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CONTENTS OF PREVIOUS NUMBER

OCTOBER 1928. NUMBER 4

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VOLUME 20 NOVEMBER, 1928 NUMBER 5

THE MAMMALIAN CEREBELLUM

A COMPARATIVE STUDY OF THE ARBOR VITAE AND FOLIAL PATTERN*

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This study represents a survey of the class of the mammalia from the point of view of the form of the arbor vitae and the folial pattern of the cerebellum. On account of certain deficiencies in the study collection, it is not yet complete. A number of the orders, such as the monotremes and the insectivores, are unrepresented by examples, and this is increasingly true in connection with many of the suborders, families, subfamilies and species which make up the class of the mammalia. As these forms become available they will be studied and will form the substance of a further communication on this subject.

In order that definite conclusions may be reached in regard to functional localization within the cerebellum on the basis of the characteristics of the folial pattern as compared with the physical organization of the animal providing the pattern, a much greater number of cerebella must be examined, not only to afford representatives of all of the orders, suborders, families and species which can be obtained, but also to provide a study of a number of individuals of each group, in order to determine whether the given folial pattern is common to all members of each species, or whether some of the variations which appear may not be individual divergences from a generally accepted pattern.

It should be a matter of considerable probability that the patterns evidenced in the disposition of the folial chain should have some direct relationship to the physical characteristics of the animal to which the particular cerebellum belongs. Therefore, in this study and in the continuation of it which will follow, the attempt has been made to collect diversified forms in order to determine whether there may be some deductions which can be drawn from the similarities or dissimilarities in the corporeal equipment of the animals and the form and pattern of the cerebellum possessed by each individual example.

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* Read at a meeting of the Association for Research in Nervous and Mental Disease, New York, December, 1926, and at the joint meeting of the Neurological Section of the Royal Society of Medicine, London, England, and the American Neurological Association, London, July, 1927.

The collection from which this material was obtained constitutes the comparative anatomic collection of the Department of Neurology of the College of Physicians and Surgeons, Medical Department of Columbia University. The collection was originated and presented to the neurologic department by George S. Huntington, the late professor of anatomy, who received the major part of the material from the New York Zoological Garden, through the courtesy of the directors of the American Museum of Natural History.

At the last meeting of the Association for Research in Nervous and Mental Disease, the subject of the cerebellum was discussed, and at that time a small portion of this still incomplete study was presented. The researches of Elliot Smith, Bradley, Bolk, Ingvar, Kappers and Edinger provide the background on which this approach to a limited problem in connection with that baffling organ, the cerebellum, has been made.

SCHEMATIZATION AND DIVISION OF CEREBELLUM

The direct focus of the study was established through the diagrams of Bolk and his observations that the arrangement of the laminae in the cerebellum represent a continuous chain, beginning at that part of the vermis which forms the cephalic wall of the ventricular fastigium, the margo mesencephalicus, and extending backward through many twists and turns in an uninterrupted series of lamellae to the final termination of the folial pattern, the last folium of the nodulus which forms the caudal wall of the ventricular fastigium, the margo myelencephalicus.

In following this folial chain, the method which alone can make possible any clear comprehension of the pattern of the cerebellum is that which has been used by all those who have studied this phase of the cerebellum, that is, the reduction of the entire cerebellum to one plane. In the preparation of my diagrams, I have not followed this scheme with rigid exactitude on account of the fact that the drawing and presentation of the structures forming the under portion of the cerebellum, chiefly the formatio vermicularis, and the convoluted twistings of its cephalic extremity forming the parafloccular and petrosal region, is difficult to schematize in its true anatomic relationships. Therefore, the patterns presented are more or less a compromise between a complete unfolding and, as it were, a spreading out of the under surface, maintaining somewhat the relationship of the upper and lower portions.

CEREBELLAR SCHEMAS

In connection with the various schemas which have already been formulated, all of them present certain advantages and disadvantages. The one which seems to me to follow most clearly the anatomic organi-

zation of the cerebellum in which all of the members of the mammalian family are considered is that which was established by Bolk. I have, however, somewhat modified this schema (fig. 1). Bolk schematized his conception of the anterior lobe as an entirely undifferentiated structure not divided into a central vermal portion with lateral expansions forming a distinct lateral hemisphere. The studies of Edinger in his conceptions of a neocerebellum and paleocerebellum, of Brouwer

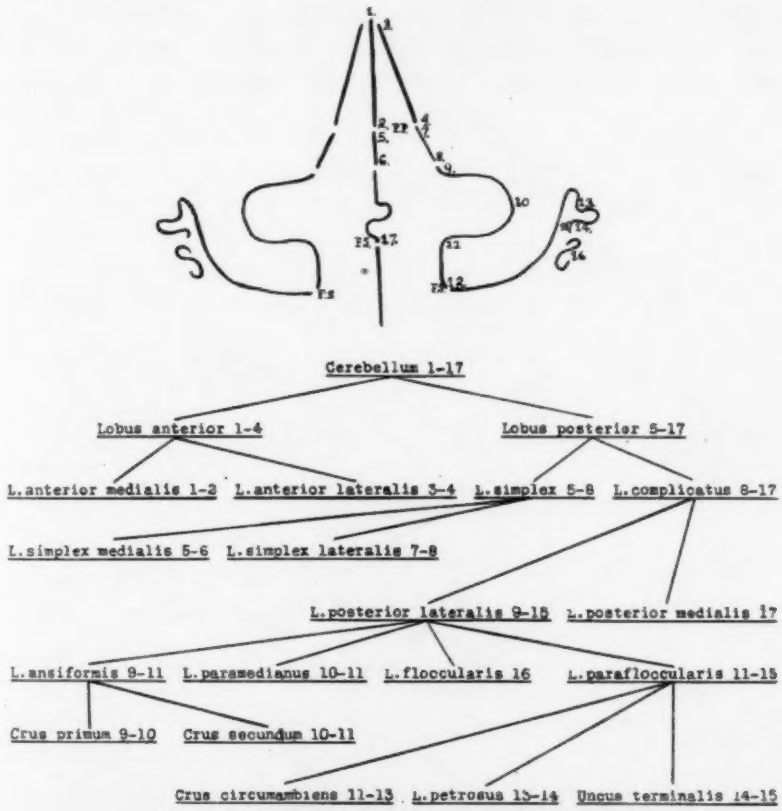

Fig. 1.—The folial chain and its subdivisions.

and his pupils, Oliver S. Strong and others in their descriptions of hemicerebellar atrophy, and of Langelaan in his embryologic identification of separate growth centers in the median and lateral portions of the anterior lobe, all make it quite certain that similar processes have been at work in the development of the anterior and posterior lobes and that each subdivision represents a central, vermal portion and a lateral hemispheral component. In connection with the anterior lobe, there cannot be any question that in certain forms even the lingula, lobulus 1, participates in the formation of the lateral extension, although

this has been denied by Kappers. A consideration of the anterior lobe in *Cetacea* indicates an absolutely definite and distinct paravermian sulcus, more definite and deeper even than that which is found in the posterior lobe, a sulcus so deep that the foliation can only with difficulty be followed from the vermal into the lateral portion with absolute certainty and definition. In practically all of the other forms studied, an indication of a vermis can be made out, not only from the elevated form of the median portion of the anterior lobe but also through the presence of short vermal sulci which can be seen extending outward for variable distances from the midline into the lateral extensions of the anterior lobe. In the modified schema of Bolk, I have,

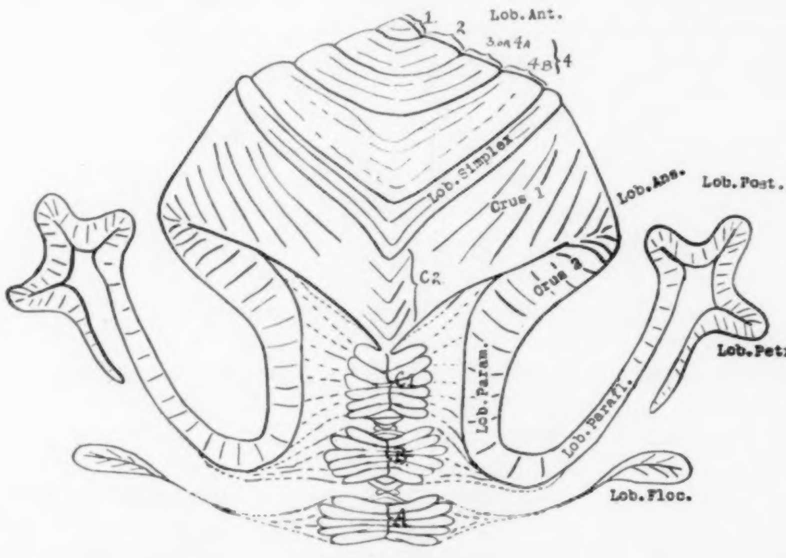

Fig. 2.—A schematic representation of the folial pattern of the cerebellum, laid out in one plane.

therefore, introduced lines representing distinct anterior lobe hemispheral constituents in the folial chain, in harmony with the arrangement universally accepted for the posterior lobe. This change has, of necessity, materially altered the numbering which Bolk used in the determination of the various parts of the folial chain, and the modified diagram of Bolk has been renumbered to make evident the various portions of the folial chain by means of numerals indicating each individual part. No useful purpose can be attained by any material change in his nomenclature, and his divisions of the cerebellum seem entirely satisfactory. The only deviation from this nomenclature is the substitution of the word circumambiens for the term circumcludens which Bolk used in connection with that part of the formatio vermicularis which lies in

close proximity with the lobulus ansiformis and the lobulus paramedianus. The term circumambiens is familiar in anatomic nomenclature, and its general connotation is more easily recognized.

In figure 2, an attempt has been made to schematize the cerebellum as it has been studied, that is, as if it were spread out in a single plane. This diagram is somewhat more similar morphologically to the various anatomic divisions as found in the subanthropoid representations which have been studied than the schemas advanced by Bradley, Bolk, Elliot Smith and others. It, of course, does not bear any resemblance to the higher primates, since in them cerebellar organization has advanced to such an extent as almost completely to transform the basic features of the cerebellum. The schema also cannot faithfully reproduce the divergent specializations shown in the cerebella of *Bradypus, Pinnipedia, Proboscidia* or *Cetacea.* The schema also indicates the connections between the various subdivision of the vermal and lateral chain in the lobus complicatus.

The following list is an enumeration of the forms which have been studied thus far in this particular investigation:

- Eutheria
  - Marsupialia
    - Diprotodontia
      - Macropus
    - Polyprotodontia
      - Thylacinus cynocephalus
  - Edentata
    - Xenarthra
      - Myrmecophaga jubata
      - Bradypus tridactylus
  - Ungulata
    - Proboscidia
      - Elephas asiaticus
    - Artiodactyla
      - Camelus bactrianus
      - Rangifer tarandus
      - Giraffa camelopardalis
      - Bos
  - Sirenia
      - Manatus
  - Cetacea
    - Delphinidae
      - Monodon monoceros
      - Phocaena communis
  - Carnivora
    - Fissipedia
      - Felis domestica
      - Canis familiaris
      - Vulpes fulvus
      - Cercoleptes caudivolvulus

Nasua rufa
Ursus americanus
Pinnipedia
Otaria gillespii
Odobaenus walrus
Phoca vitulina
Rodentia
Simplicidentata
Castor canadensis
Rattus norvegicus albinus
Cavia porcellus
Dasyprocta agouti
Duplicidentata
Lepus cuniculus
Chiroptera
Megachiroptera
Pteropus
Primates
Lemuroidea
Lemur varius
Anthropoidea
Platyrrhina
Hapale jacchus
Cebus lunatus
Ateles ater
Catarrhina
Macacus rhesus
Cynocephalus babuin
Simia satyrus
Gorilla gorilla
Anthropopithecus troglodytes
Homo sapiens

There are a number of elements which introduce a degree of uncertainty into any presentation of the pattern of the arbor vitae and the arrangement of the folial chain. In connection with the arbor vitae the exactness of the median section makes a considerable difference, for a deviation from an almost exact sagittal section will produce a deformation of the arbor vitae which will materially alter the origin of the various medullary rays and, therefore, influence the lobulation which is dependent on the divisions of the medullary substance. The age of the animal also seems to exert, at least in some forms, a definite influence in the arrangement of the folial pattern. In the dog, for instance, one specimen in the collection, small and apparently from an immature animal, presented a perfectly straight vermis in connection with lobuli C 2 and C 1, whereas a cerebellum known to have been obtained from an adult animal showed a definite sigmoid gyrus in this portion of the vermal pattern.

THE DIVISION OF THE CEREBELLUM

The two chief landmarks in the study of the arbor vitae appear to be the fissura primaria and the ventricular fastigium. The other important landmark in the arbor vitae is the fissura secunda. In almost all of the forms examined, it was relatively easy to determine the position of the fissura primaria by its relationship to the ventricular fastigium, the fissure which penetrated the deepest, approached most closely to the ventricular fastigium and was the most vertical of the fissures of the arbor vitae being accepted as the fissura primaria. The fissura primaria and the ventricular fastigium divide the cerebellum into an anterior and a posterior lobe. The only order which presented any considerable problem in this differentiation was the cetacean in which great difficulty was experienced in determining the fissura primaria, and only a tentative decision could be reached through a study not only of the arbor vitae but also of the arrangement of the lobules in the folial pattern. Whether the assumption arrived at in the description of the arbor vitae and the folial pattern in the cetacean subdivision was the correct one is a question, but the decision was the best that could be reached under the circumstances. The fissura secunda was assumed to be the cleft separating lobulus B and lobulus C. This differentiation was in almost all cases a simple one to make. The continuation of this fissure laterally almost invariably led to the angle between the lobulus paramedianus and the lobulus paraflocculatis, thus conforming with the embryologic differentiation in which the association of the vermal and lateral portions shows lobulus C 1 to be associated with the lobulus paramedianus and lobulus B with the paraflocculus. This relationship is definitely settled in a considerable number of forms in which the connection between the lateral and the vermal folia is clearly visible, in many cases surface folia of lobulus C 1, and in other cases a submerged folium representing C 1, being found to be directly continuous with the most caudal folia of the lobulus paramedianus. No useful purpose seems to be gained by dividing the cerebellum into a middle and a posterior lobe through the location of the fissura secunda.

The division of the arbor vitae, following on the identification of the fissura primaria, the fissura secunda and the ventricular fastigium is, in general, a fairly simple matter, although in some details it presents conditions which may be susceptible of one or another interpretation. These differences of interpretation, however, are, in the great majority of cases, simply matters of detail and do not affect any of the essential characters of the division of the cerebellum into its constituent parts. The chief region in which these differences of interpretation may arise is in the origin of the second and fourth branches. The first branch is usually fairly clear, although it may be extremely rudimentary, of considerable size or form a lingula. The rays forming lobulus 2 arise

singly or as a series of branches from the cephalic protrusion of the medullary substance. These may be fairly discrete, or a branch may be present which, arising from the dorsal and more caudal portion of the cephalic protrusion, may introduce the question as to whether the ray should be interpreted as an independent ray 3, or be grouped with either ray 2 or ray 4. The exact point of origin of the feet of these rays from the medullary substance may be changed by a slight deviation from an exact median section of the arbor vitae, and this may throw a portion of lobulus 2 into a distinct lobulus 3, or shift a distinct lobulus 3 into lobulus 4. The arrangement, however, of the folia forming the lateral outgrowth from lobuli 2, 3 and 4, is so simple and, in general, so uniform, that it is doubtful whether any definitely distinct function can be allocated to these portions of the cerebellum, which would be influenced by one group of folia belonging to lobulus 2, forming an independent lobulus 3 or belonging to lobulus 4. The arrangement of these lobules is, in general, so uniform throughout the entire series of cerebella which have been examined, that it is in all probability true that these lobuli serve portions of the body structure which are relatively uniform throughout the entire series, and do not present any material change in one form as compared with another. The other branching of the arbor vitae in which there may be some difference of opinion is the exact determination of the point at which ray C takes its origin and its division into ray C 1 and ray C 2. Since, however, these lobules form a subdivision of a larger lobulus which shows, in general, a considerable degree of homogeneity throughout the entire series, here again the exact allocation of two or three folia to either one or the other lobule cannot be of great significance. The major variations in lobuli 2 and 4 are associated chiefly with the size and number of the rays acting as a scaffolding for the respective lobuli, and this, in general, seems to be more or less dependent on the corporeal bulk of the individual animal. Whether functional variations may also emerge on further study is a question only the future can answer. Continued investigation may disclose closer anatomic and functional relationships than are at present available. If this is the case, the variations in the anatomic arrangement of this portion of the cerebellum may assume a significance which they do not now possess.

So far as the connection between lobulus B and the paraflocculus and lobulus A and the flocculus is concerned, in some forms a definite bridgelike connection can be determined connecting lobulus B and the paraflocculus. When a direct connection is lacking, the general trend of the peduncle in the center of the folial roset of lobulus B is definitely turned in the direction of the angle of transition between the lobulus paramedianus and the lobulus parafloccularis. The connection between lobulus A and the lobulus flocularis is never so distinct. The line of

the peduncle is clearly ventral to that taken by the peduncle of lobulus B and extends more or less in the general direction of the lobulus flocularis. In the majority of instances, these peduncles merge into the general medullary substance, and the only anatomic indication of an actual connection between the vermal folia and the folia of the lateral chain that can be determined is an indefinite ridge, which in many cases soon loses any degree of definition which it more centrally may have had.

The identification of the various fissures and sulci of the folial chain can be determined with considerable accuracy by identifying the fissures as they separate the various lobules of the arbor vitae and by following them outward into the folial chain. In most instances, this was fairly simple, although in the cetacea and in the elephant a clear differentiation between lobules was impossible on account of the fact that the folia making up the various lobules do not fall into clearcut divisions, either mesially or laterally, since there are large folial masses in the depths of the fissures which form bridges between the preceding and succeeding lobules, and it is impossible to separate entirely the lobules without tearing across groups of submerged folia. In certain instances, the apparent separation of the lateral folia into lobules did not at all agree with the lobulation of the arbor vitae. This is particularly true of *Cetacea* in which the lobules of the lateral portion of the cerebellum are apparently connected with equal parts of preceding and succeeding arbor lobules, so that each lobulus of the arbor is connected with two lobuli in the lateral lobulation, and vice versa.

The Folial Chain.—In general, the folial chain is fairly easy to follow, and, as emphasized by Bolk, it is continuous from the most cephalic folium of lobulus 1 to the most caudal folium of lobulus A, both in the vermis and in the hemisphere. In the parafloccular portion of the cerebellum, considerable difficulty arises in following the folial chain on account of the fact that in the depths of a fissure the chain may turn at right angles and proceed in most unexpected directions. A careful folium-by-folium investigation will, however, in all cases show the correct sequence of folia. The chain is complete, and not at any point is it impossible for one to follow the serial arrangement of the folial pattern.

In certain forms, an absolutely immediate connection between the termination of the lobulus paraflocularis and the beginning of the lobulus flocularis is difficult if not impossible to establish. This may be due to the fact that the lobulus paraflocularis is the most variable of all the portions of the lateral folial chain, and therefore some of its folia may be suppressed and a direct connection between the two not exist.

DETAILED DESCRIPTION OF THE ARBOR VITAE AND THE FOLIAL PATTERN IN CERTAIN OF THE MAMMALIA

The following descriptions are the result of a detailed examination of the arbor vitae and the folial pattern in the various animals which have afforded the material for this study. In connection with the illustrations, in all cases the cephalic aspect is to the reader's left hand, while the caudal aspect is to his right, and the free surface of the cerebellum is away from the reader, while the neuraxial aspect is toward him.

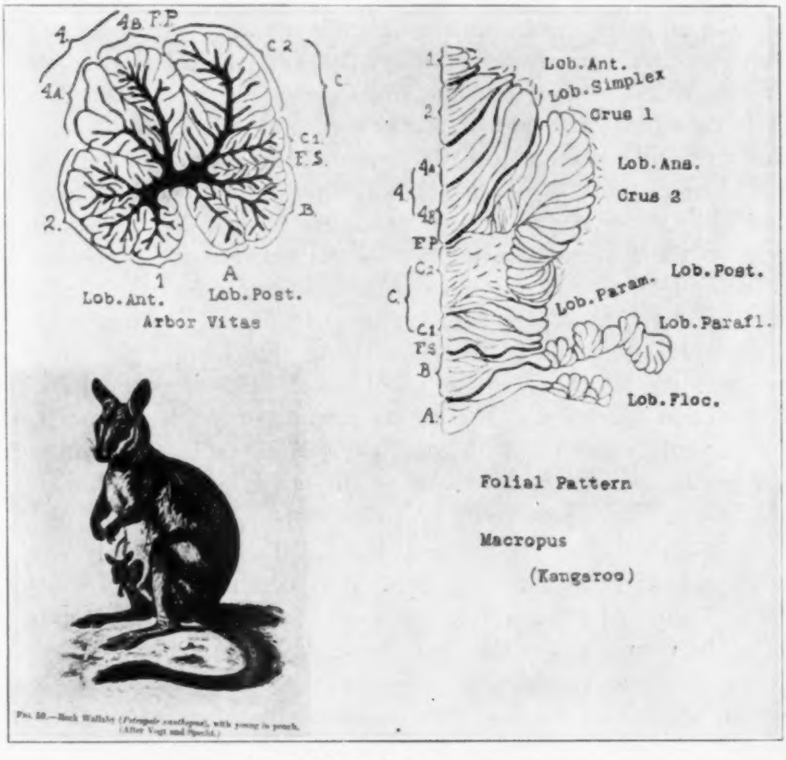

Fig. 3.—Macropus (kangaroo).

The arrangement of the folial pattern does not need any explanation, and a representation of the physical form of the animal in question has been provided in order that there may be kept uppermost in mind the physical characteristics of the particular animal in connection with the pattern which his arbor vitae and folial chain present.

MACROPUS (KANGAROO)

The median section of the cerebellum of the kangaroo presents a comparatively circular outline, interrupted in its lower portion by a fairly wide open ventricular fastigium. The arbor vitae is divided into two fairly equal halves by the fissura

primaria and the roof of the fourth ventricle, the two halves representing the anterior and posterior lobes. The fissura primaria is somewhat curved owing to the conformation of lobulus C, but it is essentially perpendicular as is also the fastigium which reaches the medullary substance. The fissura secunda is situated between lobuli B and C and divides the posterior lobe into a larger dorsal and a smaller ventral portion.

The medullary substance is disposed in the center of the cerebellum, being divided by the constriction produced by the approach of the fissura primaria to the ventricular fastigium, into an equally divided medullary substance of the anterior and posterior lobes. The prominent character of rays 4 and C 2 gives the impression of a U-shaped disposition of the medullary substance. The main mass of the medullary substance is almost horizontal, with a slight inclination upward and backward. The branches of the medullary substance are heavy, and there is a considerable degree of division of the medullary branches producing a moderately rich foliation.

THE MEDULLARY RAYS

The first definite branch of the medullary substance ray 1 is a fairly robust stalk which arises from the under surface of the medullary substance, proceeds almost directly downward, giving off a few side branches, and terminates in a bifurcated extremity. Ray 2 is much heavier, comprising the entire extension forward of the medullary substance; it quickly divides into two major subdivisions, the first of which appears as a single stem which gives off a few lateral derivatives and ends in a branched extremity. The second branch, of about equal size, at once divides into two subdivisions which give off lateral branches. There is no ray 3. Ray 4 arises from the upper aspect of the medullary substance as a heavy stalk which almost immediately divides into two stems, ray 4 A and ray 4 B. The former proceeds forward and upward, giving off lateral branches, and ends in two rather elongated twigs. Ray 4 B proceeds more directly vertically and then arches forward, somewhat overhanging ray 4 A. It presents a small number of lateral branches and ends in a considerable spray. The medullary substance of the posterior lobe is heavy and gives rise to a number of stout branches. Ray C arises from the dorsocaudal angle, gives off a number of anterior unbranched prolongations and divides into a vertical C 2 and a horizontal C 1. Ray C 2 proceeds upward and forward, giving off undivided branches, and ends in an arched formation forward which somewhat overhangs lobulus 4. A well defined ray C 1 arises from the lower portion of C 2 and passes almost directly caudally, giving off lateral branches. The caudal extremity of the medullary substance of the posterior lobe then gives rise to a single stout stem which almost immediately divides into two portions forming a subsidiary division, the upper being the simpler and giving off lateral branches, and the lower giving origin at its extremity to an extensive dendritic spray. Ray A arises close to the caudal extremity of the fastigium and consists of a slender branch which divides into a number of subsidiary twigs.

THE LOBULES

The lobules as shown on the median section consist of a conspicuous lobulus 1, which forms the entire cephalic wall of the fastigium and presents a number of small folia. Lobulus 2 is divided into two definite subdivisions, corresponding with the two chief branches of the anterior extension of the medullary substance. Lobulus 4 is subdivided into lobulus 4 A and lobulus 4 B. Lobulus 4 A presents on its surface two chief folia which are rather broad. Lobulus 4 B

is relatively slender, and simple in its deeper portion, but rather more complicated at its termination, undergoing a considerable degree of secondary division. Lobulus C 2 is relatively large, consisting chiefly of well defined folia, and forms the summit of the arbor vitae. Lobulus C 1 is simple and presents only three or four small folia on its surface. Lobulus B is subdivisible into a much larger ventral and a smaller dorsal portion, the larger ventral sublobulus dividing into a spray of subsidiary rays. Lobulus A is a simple structure forming the caudal limit of the fastigium and consists of only a few rather wide folia.

THE FOLIAL PATTERN OF MACROPUS

The folial pattern shows the division of the cerebellum into an anterior and a posterior lobe by means of the fissura primaria which arises at almost the midpoint of the median section of the vermis. It turns forward, however, thus separating a smaller anterior from a larger posterior lobe, and swings outward and forward toward the periphery of the hemisphere. The fissura secunda divides the vermis of the posterior lobe into a larger dorsal and a smaller ventral portion. It continues outward, limited throughout its entire extent by true folia, and limits caudally the lobulus paramedianus.

Lobulus 1 consists of four folia all of which are confined to the vermis except the most caudal one which shows a slight tendency to extend outward into the hemisphere. Lobulus 2 presents an easily recognized division into vermal and lateral portions. The cephalic and caudal folia do not extend as far laterally as the intermediate folia. Only two of the folia actually reach the periphery, and they are drawn together into a single peduncular root. Most of the folia show vermal subdivisions. Lobulus 4 presents two definite subsidiary portions. Lobulus 4 A consists of two broad folia which join before reaching the periphery. Lobulus 4 B is extensive on median section, but is drawn out laterally into a relatively condensed insertion into the medullary substance, the eight or ten vermal folia being reduced to two at the lateral extremity of the lobulus. This lobulus presents also a definite distinction between the vermal and lateral portions, evidenced by the swing forward and the limited extent of some of the secondary sulci. Lobulus C is subdivided into a more extensive cephalic portion, lobulus C 2, and a less extensive caudal portion, lobulus C 1. Lobulus C 2 is rather extensive and consists of a series of vermal folia which are continuous laterally with a broad bare area of medullary substance crossed by broken sulci. The folia resume their normal appearance lateral to this denuded area as parallel laminae of gray matter, the most cephalic presenting a fairly simple arrangement corresponding to the position of the lobulus simplex. The mesial and lateral portions of this lobulus are barely continuous. Caudal to the lobulus simplex a fan-shaped arrangement of small submerged folia appears, which rather suddenly elongate forming a definite lobulus ansiformis, consisting of a relatively well developed crus 1 and crus 2. The two crura form a fairly definite sulcus intercruralis. The caudal portion of lobulus C 2 consists of a series of small folia which present a leaflike arrangement arising from the bare connecting area and implanted by a single medullary peduncle into the white substance. These folia are succeeded by a series of laminae which rapidly increase in lateral extent until they reach the midline. Lobulus C 1 consists of a few vermal folia which extend outward as true folia to form the lobulus paramedianus. These folia are narrow, sinuous and somewhat irregular in arrangement. Lobulus C 1 and the lobulus paramedianus are thus confluent and do not present a definite demarcation in their vermal and lateral constituents. Lobulus B presents a collection of rather irregular vermal folia, which converge to form definite lateral extensions which

come into close relationship with the paramedian formation and the inception of the lobulus paraflocularis. The lobulus paraflocularis consists of a number of folia arranged in rosets which arise from a single stem and are applied to the lower and outer margin of the ansiform and paramedian formations. The lobulus paraflocularis turns backward to form a fairly definite but thick uncus terminalis. Lobulus A consists of two small subdivided folia which are continued outward as a single folium which is apparently continuous with the lobulus flocularis. The lobulus flocularis consists of six or seven small folia forming two rosets which are situated between the paraflocularis and the cerebellar peduncle.

Lobulus 1 and lobulus 2 have independent peduncular implantations. Lobulus 4 presents a single implantation which chiefly serves lobulus 4 B. The lobulus ansiformis forms a large peduncle, as does also the lobulus paramedianus; while the lobulus paraflocularis possesses a separate implantation lateral and ventral to the preceding lobules.

PHYSICAL CHARACTERISTICS OF MACROPUS

This kangaroo, about as large as a good-sized sheep, represents *Diprotodontia* and is a much more highly specialized form than *Thylacinus cynocephalus*, the representative of *Polyprotodontia*. The head is rather small, the eyes are situated well forward, possess overlapping fields of vision and are conjugated in their movements. In this and all other forms known up to the primates, the movements of the eyes are rather limited and are apt to be substituted for by movements of the head, the gaze being directed toward the object more by the movement of the head on the neck than by the actual change of axis of the eyes. The ears are prominent and are freely and independently movable. The jaws are not massive, and the tongue is not prominent. The neck is rather short. The body is rather large and heavy, the thoracic portion being less massive than the abdominal segment. The limbs are disproportionate; the fore limbs are short and rudimentary, while the paws are well developed and capable of much pronation and supination. They function almost as hands, being capable of holding and also of a fair degree of unilateral independence. The hind limbs are excessively developed into extremely long and powerful extremities which are capable of propelling the kangaroo at a rapid pace. A large kangaroo can cover 26 feet at a stride when at high speed. When progressing slowly, the kangaroo may go on all fours. When at high speed it leaps with both hind limbs acting together. It does not land on its fore limbs; these are tucked up against the thorax. In fighting with its adversaries the kangaroo will seize its opponent with its fore limbs and rip its enemy's body with the sharp claws of the hind limbs. It will also submerge its opponents with its fore limbs. There is little independence of the hind limbs. The tail is elongated and forms about two thirds of the length of the animal, heavy at its root and slightly tapering, and is used as a third leg of the tripod in the sitting position. When the animal is in motion, the tail has an extensive and efficient equilibratory and steering function. In standing, the kangaroo is supported entirely by the hind limbs so that it has an extensive need for equilibration, the body being fairly well balanced in its caudal half behind the limb support by means of the tail. In progressing, the kangaroo presents an extremely efficient equilibratory apparatus, being likely to propel itself 26 feet and land in a position which will at once allow another great leap. In the leaps, the tail is extended stiffly and acts efficiently as a counterbalance and also as a sort of rudder.

THYLACINUS CYNOCEPHALUS (TASMANIAN WOLF)

The general outline of the arbor vitae in the Tasmanian wolf presents a considerable degree of similarity to *Macropus*, being roughly quadrilateral in outline. It is not so equally divided into anterior and posterior lobes for in *Thylacinus* the posterior lobe has increased in size and apparently in importance. The division into anterior and posterior lobes is produced by the fissura primaria and the ventricular fastigium which have a distinctly oblique disposition from before downward and backward, the latter being in direct prolongation with the former. This arrangement apparently results from an increase in lobuli 2 and C. The general arrangement of the medullary substance is similar to that of *Macropus*, as it is constricted by the approach of the fissura primaria to the ventricular fastigium, and then expands into masses of considerable size

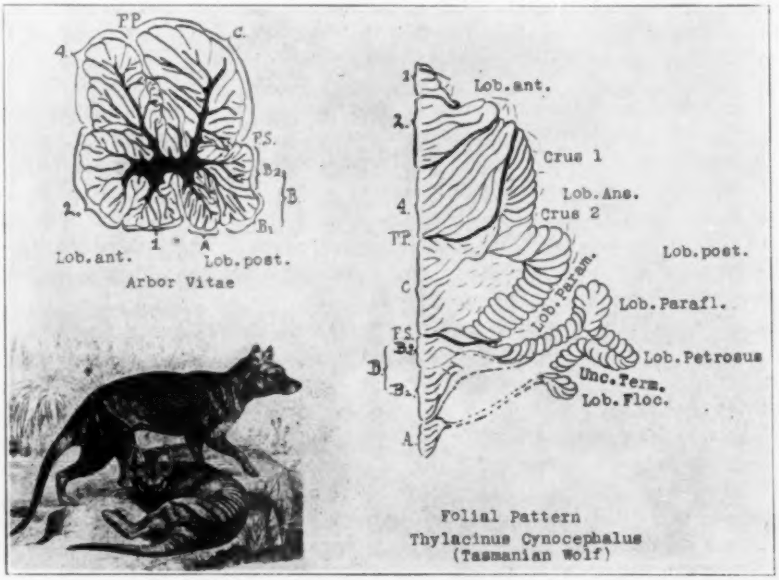

Fig. 4.—Thylacinus cynocephalus (Tasmanian wolf), pouch dog.

in both the anterior and posterior lobes. It presents a distinctly U-shaped configuration through the extension upward of the relatively heavy rays 4 and C. The fissura secunda occupies relatively the same position as in the kangaroo, being situated between lobuli B and C. There is a definite increase in the size and complexity of the folia of the posterior lobe.

THE MEDULLARY RAYS

The medullary rays are similar to those seen in the kangaroo. Ray 1 is a large heavy branch arising from the ventral surface of the medullary substance. It at once divides into two branches, the first being rather slender with a few side branches and the second being heavier. Each of these subdivisions end in terminal bifurcations. Ray 2 consists of two stems the first being quite heavy and the second quite slender. Both these stalks undergo a rather simple division. Ray 3 is represented only by a small branch which lies in the depths and fails to

reach the surface and appear in the folial pattern. Ray 4 is a long slender stalk inclined cephalad which gives rise to a major subdivision cephalically which forms the first part of lobulus 4. Its summit is somewhat less complicated than the summit of this ray in *Macropus*, but its caudal branches exert a definite influence on the folial pattern. Ray C is a thick heavy stem directed obliquely upward and backward, and it is strongly developed cephalically, considerably overhanging ray 4. It gives off a number of long, slender cephalic branches, shorter, coarser caudal divisions and an apical spray. There does not appear to be a definite ray C 1, although the lowest branch in its divergent behavior in the folial pattern appears to be the homologue of ray C 1. Ray B presents an extensive development arising as a heavy caudal extension of the medullary substance which immediately divides into a rather complicated horizontal branch and a descending branch which is subdivided. Ray A is more complex than in *Macropus* showing a definite secondary branch proceeding caudally from a point near the origin of the ray.

THE LOBULES

The lobular pattern is similar to *Macropus*, with the exception that a definite lobulus 3 does not develop. The ray which is the homologue of the ray forming lobulus 3 in *Macropus* appears to be incorporated with ray 4, so that lobulus 4 represents a consolidation of lobuli 3 and 4 as they appear in *Macropus*. Lobulus 1 consists of two rather simple groups of folia arising from a common stem. Lobulus 2 is composed of larger folia which fall into two groups. Lobulus 4 presents a distinctly conical appearance and consists of a cephalic group of folia corresponding to lobulus 3 and an apical group which also form the cephalic wall of the fissura primaria. Lobulus C is more extensively developed in its upper and cephalic portions and less so in its lower and caudal portion. Its apex is directed forward overhanging the fissura primaria and lobulus 4. It is somewhat suggestive in its morphology of the lobulus impendens, which is so conspicuous in certain of the rodent cerebella. Its upper portion is somewhat wider than its base. It is constituted mainly of rather broad folia. It does not show any definite division into sublobules C 1 and C 2, although the folial pattern shows a definite difference in the lateral extensions of the cephalic and caudal portions of the lobulus. Lobulus B is extensive being composed of two almost independent groups of folia—the upper group, lobulus B 2, being greater in number, more compact and shorter, as compared with those which form lobulus B 1. Lobulus A is well developed and presents in the depths of the fissure separating lobuli A and B a distinct caudal branch.

THE FOLIAL PATTERN OF THYLACINUS CYNOCEPHALUS

In the folial pattern, the fissura primaria has moved forward chiefly on account of the increased development of lobulus C. The fissura primaria swings outward, slightly backward and then almost directly forward forming a definite loop. The fissura secunda appears between lobuli C and B, and its lateral extension clearly delimits the lobulus paramedianus.

Lobulus 1 is represented by a number of small vermal folia the most caudal of which develops a lateral extension. Lobulus 2 presents a considerable number of vermal folia which suffer a great reduction in number as they are continued outward into the hemisphere. The folia are irregular in width and disposition. Lobulus 4 is definitely more developed than it is in *Macropus*, presenting a number of thin striplike folia which run forward and outward. There is some slight evidence of a vermal formation toward the midline in lobulus 4. The

caudal portion of lobulus 4 shows the influence of the submerged folia seen in the depths of the fissura primaria which emerge on the surface in swinging lines more or less parallel with the fissure. Lobulus C is divided into two portions: A cephalic portion presents a definite vermal component, and then becomes constricted and is continued laterally into an irregular area which is marked by broken sulci. This area then expands as the lateral portion of the lobulus presenting a multifoliated structure, forming crus 1 of the lobulus ansiformis. The caudal portion of lobulus C shows a definite vermal foliation which is succeeded by an undifferentiated area of bare medullary substance marked by a number of small broken irregular lines. Lateral to this bare area, the foliation again appears with the development of a well defined crus 2. Crus 2 is then succeeded by a well defined lobulus paramedianus which bounds caudally the bare medullary area already mentioned. At the end of the lamellar chain forming the lobulus paramedianus a folium appears which is continuous with a submerged folium in the depths of the fissura secunda. This establishes a definite connection between the vermis and the lobulus paramedianus and fixes the position of the fissura secunda caudal to this folium. Lobulus B is subdivided into two portions: The cephalic portion shows definite vermal characteristics and is continued laterally by means of one or two wavy folia, with the lamellar chain forming the beginning of the lobulus parafloccularis. The caudal portion of lobulus B is vermal and shows a stalklike extension which is connected with the mesial extremity of the lobulus parafloccularis. The lobulus parafloccularis is directly continuous with the caudal termination of the lobulus paramedianus and continues forward as a chain of small folia which parallels the lobulus paramedianus and then develops a foliated roset which encircles the apex of the lobulus ansiformis. This foliated structure then turns back on itself and gives out a lateral group of folia forming a definite lobulus petrosus and terminates as a well defined uncus terminalis. Lobulus A consists of a group of folia which is entirely vermal, but is connected with the base of the lobulus flocculus by an ill defined peduncle. The lobulus floccularis itself consists of a simple folial roset situated between the lobulus parafloccularis and the cerebellar peduncle.

The implantation of the folia into the medullary substance laterally consists of a single peduncle for lobulus 1 and the cephalic portion of lobulus 2. The caudal portions of lobulus 2 and lobulus 4 are implanted by a single peduncle, while the lobulus ansiformis and the lobulus paramedianus rest on the medullary substance by means of a broad peduncle. The entire lobulus parafloccularis has a broad attachment to the medullary substance surrounding the implantation of the ansiform and paramedian formations.

PHYSICAL CHARACTERISTICS OF THYLACINUS CYNOCEPHALUS

The Tasmanian wolf is a large wolflike marsupial measuring about 4 feet from the nose to the root of the tail. It closely resembles the boar-hound in appearance, having a large, heavy head, rather short, mobile ears, a thick, short neck, four strong extremities adapted to a speedy running gait, a thick body and a doglike tail. It has a dentition typical of carnivorous animals, although not the same dental formula, strong heavy jaws and powerful teeth. The eyes are situated anterolaterally, possess overlapping fields of vision and are possessed of conjugated movement. This animal is essentially a quadrupedal mammal, the fore and hind limbs being used in progression equally. The gait is essentially doglike, a walk, trot or gallop. It is capable of considerable speed. There is

no greater unilateral independence of the fore limbs than is manifested by the average dog. The Tasmanian wolf is a ferocious, combative, solitary animal, possessing a considerable degree of agility and grace in its movements.

BRADYPUS TRIDACTYLUS (THREE-TOED SLOTH)

The three-toed sloth presents a cerebellum of much more simple organization than its fellow representative of the edentate class, the anteater. The form of the arbor vitae is simple, and irregularly circular. The branches forming the rays are relatively undifferentiated, presenting little secondary branching and little

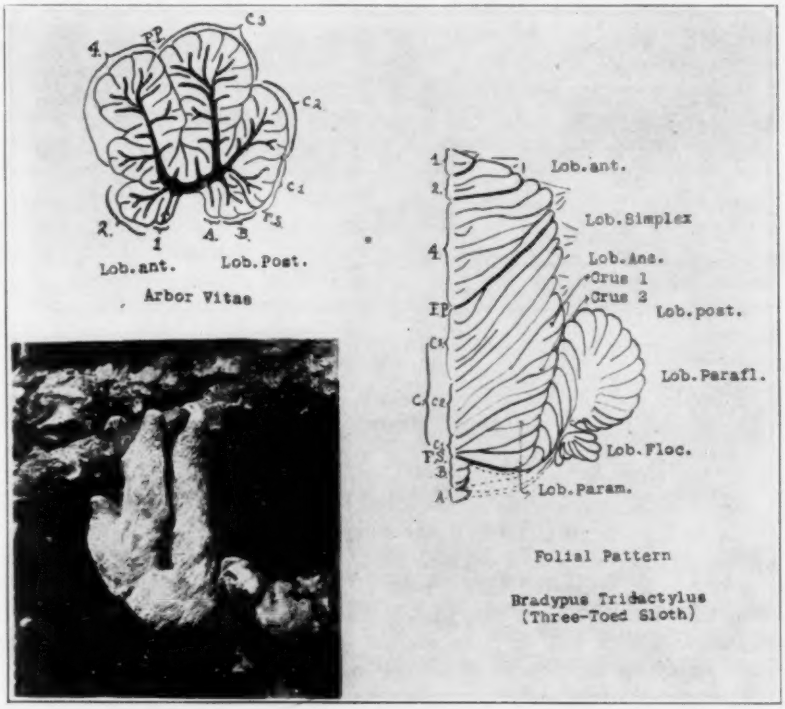

Fig. 5.—Bradypus tridactylus (three-toed sloth).

terminal arborization. The outline of the arbor vitae is irregular, each lobule standing out by itself, there being a considerable independence in the summits of the various lobes as the fissures cut rather deeply in between the lobules, thus isolating them from each other. The upper portion of lobulus C 3, however, presents a mushroomed-out appearance. The arbor vitae is divided into a smaller anterior lobe and a larger posterior lobe by the fissura primaria and the ventricular fastigium. The fissura primaria is directed from before downward and somewhat backward, its termination directly approaching the ventricular fastigium which is wide open and directly limited cephalically by the medullary substance. The fissura secunda is situated as usual between lobuli B and C and is directed backward and markedly downward. The medullary substance is distributed more or less in the form of a thick arc lying directly above the ventricular fastigium,

drawn out somewhat more into the posterior lobe than into the anterior lobe, and resembling a U through the well developed rays 4 and C 3. The branching takes place chiefly at the cephalic and caudal ends of the medullary substance.

THE MEDULLARY RAYS

Ray 1 is a simple stem not possessing any lateral outgrowths. It bifurcates at the summit into two subrays. Ray 2 is a simple ray, which arises from the cephalic extremity of the medullary substance, gives off one lateral branch and then divides into two short terminal processes. There is no ray 3, although its homologue exists in a simple cephalic branch from the lower part of ray 4. Ray 4 is a relatively slight single stem which gives rise to a small number of lateral outgrowths which arise at almost right angles to the main stem, terminating in bifurcated extremities. There is practically no secondary division of any of these subrays. Ray C may be divided into two long rays, C 3 and C 2, and a shorter stem, ray C 1. Ray C 3 proceeds forward somewhat overhanging ray 4 which immediately precedes it. It presents only a few side shoots which are in turn meagerly subdivided. Ray C 2 is simple, arising as a direct caudal extension of the medullary substance and showing but little redivision. Ray C 1 arises from the base of ray C 2 and undergoes a simple subdivision. Ray B is composed of a single branch arising from the ventral extremity of the medullary substance, with only a few branches, and is directed chiefly downward. Ray A is a single, undivided small ray, lying immediately caudal to the ventricular fastigium.

THE LOBULES

The lobules forming the arbor vitae are simple. Lobulus 1 presents a single, partially divided folium. Lobulus 2 presents only two broad folia, one of which shows a vermal subdivision. Lobulus 4 is separated considerably from lobulus 2. Its folia are disposed almost at right angles to the central stem, are irregular and simple in their arrangement and not at all extensive. Lobulus C presents three portions, a lobulus C 3 which has some of the characteristics of the lobulus impendens of the cerebellum of the rodent, partially overhanging lobulus 4, a lobulus C 2 which is smaller than lobulus C 3, and a lobulus C 1 which is inconspicuous and really is only a part of lobulus C 2. Lobulus B appears as a relatively meager lobulus with only two surface folia. Lobulus A consists of a single folium forming the caudal wall of the fastigium.

THE FOLIAL PATTERN OF BRADYPUS TRIDACTYLUS

The folial pattern of the sloth is the simplest found in any of this series, there being practically no lateral development and no ansiform formation worthy of the name. The folial pattern seems largely a simple extension of the vermis without any complications in the arrangement of the lamellae, each folium succeeding the preceding one in an almost uninterrupted series from lobulus 1 to lobulus C 1. The fissura primaria is rather cephalad to the midpoint of the folial pattern and proceeds forward and outward. The fissura secunda occupies its regular position between lobuli B and C, its lateral extension sharply delimiting the lobulus paramedianus which comes to a rather sudden termination.

The various lobuli show a simple arrangement. Lobulus 1 consists of a single folium which is subdivided only in the region immediately adjoining the midline. Lobulus 2 presents two folia which are subdivided in the median plane but which present definite evidence of lateral extension. Lobulus 4 shows a rather definite differentiation into two portions: the cephalic portion is formed by two simple folia

which are extended considerably laterally, while the succeeding three folia are subdivided mesially and do not extend as far laterally as does the cephalic portion.

Lobulus C presents a rather simple formation, divisible into sublobuli C 3, C 2 and C 1. Lobulus C 3 consists of three or four parallel surface folia which extend forward and outward. Lobulus C 2 is constituted by about five striplike surface folia, the middle three of which show a rudimentary attempt at the formation of a lobulus ansiformis. Lobulus C 1 presents a divergent group of folia representing the lobulus paramedianus. These folia radiate outward in a fanlike manner from the midline toward the periphery. Lobulus B consists of three small vermal folia connected by means of an ill defined peduncle with the lobulus parafloccularis. The lobulus parafloccularis appears as a direct continuation of the caudal termination of the folia forming lobulus C 1, producing a rather large wheel-like arrangement of lamellae proceeding forward and then returning upon itself, applied to the under and outer surface of the lateral portion of the hemisphere as far forward as the caudal portion of lobulus 4. Lobulus A consists of one small vermal folium which is connected apparently by means of an indefinite peduncle with a simple group of folia forming the lobulus floccularis, which appears as a folial roset continued into a short lamellar chain.

The implantation of the folia into the medullary substance laterally follows a rather simple arrangement. Each one of the lobules of the anterior lobe and the subdivisions of lobulus C has a single independent peduncle. The parafloccular formation has a broad attachment ventral and lateral to lobulus C.

PHYSICAL CHARACTERISTICS OF BRADYPUS TRIDACTYLUS

The three-toed sloth is a peculiar, much specialized animal, which is almost blind and practically deaf. It is a sluggish creature, passing the greater part of its existence pendant from the limbs of trees or curled up with its head between its fore limbs. It is absolutely incapable, under any circumstances, of rapid, graceful movement. It wanders slowly and with excessive caution from limb to limb of trees. H. W. Bates states that the sloth is able to swim but he does not describe the swimming movements. When placed on its belly, the sloth sprawls out, and it can progress only with the greatest difficulty and slowness, crawling and dragging itself along with its claws, the soles of the feet being turned inward. The neck is short and mobile; the eyes are placed anteriorly with overlapping fields of vision; external ears are either rudimentary or not present. The limbs are adapted to a hanging position, the claws being curved in such a way as to favor the grip on the limb of the tree. In feeding, the sloth slowly and awkwardly drags leaves, twigs, etc., into its mouth with the fore limbs. The tail is only rudimentary.

MYRMECOPHAGA JUBATA (GREAT ANTEATER)

The form of the arbor vitae in the great anteater is definitely circular, with the exception of the irregularity in outline formed by the summit of ray C. The ventricular fastigium and the fissura primaria are not exactly opposite each other, the latter being situated somewhat caudal to the former. The fissura primaria is practically vertical. The fissura secunda appears between lobuli B and C, in an almost directly horizontal position. The arbor vitae is divided by the fissura primaria and the ventricular fastigium, with a smaller anterior and a larger posterior lobe. In its general appearance, the cerebellum is a relatively highly differentiated organ. The rays are delicate, numerous and extensively branched. The medullary substance is more compact and is not drawn out into

the stout stems which are seen in the marsupials and *Bradypus*. The amount of medullary substance is about equally divided between the anterior and posterior lobes in the center of the arbor vitae.

THE MEDULLARY RAYS

Ray 1 is highly developed. It consists of a strong single ray, which immediately branches into an anterior and posterior division. The rays forming the second lobulus in the anteater are situated in much the same position as these rays in the marsupials. They are, however, more richly subdivided, and the formation of the secondary folia is considerably greater than was the case in the preceding forms. There is no definite ray 3, ray 4 arising as a thick, heavy protrusion from the upper portion of the medullary substance of the anterior lobe, and almost immediately dividing into two strong rays, one of which pro-

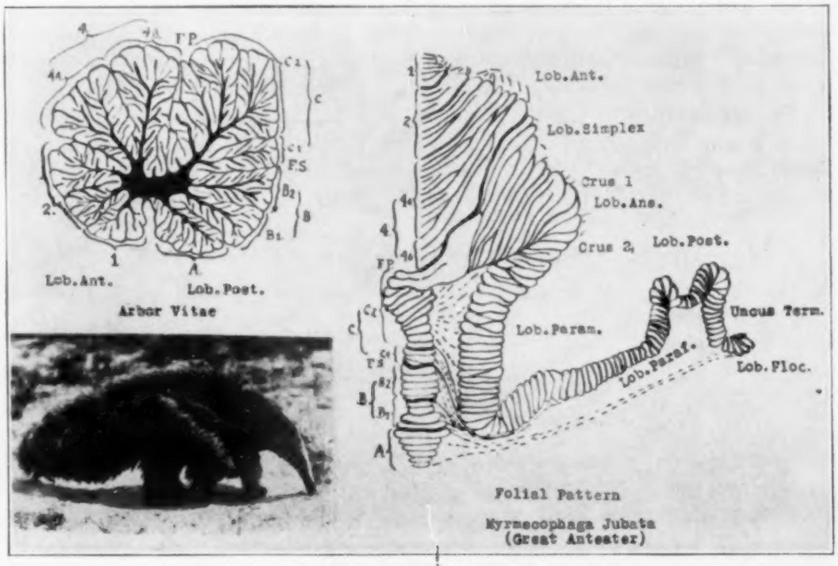

Fig. 6.—Myrmecophaga jubata (great anteater).

ceeds forward and upward and the other almost directly upward. These both undergo repeated branching and each terminates by dividing into strong secondary divisions which again divide. Ray C is drawn out more caudally than it is in the marsupials. It gives off rami dorsally as it proceeds upward, and then ends by dividing into two well developed terminal rays, the cephalic of which proceeds directly upward, dividing as it does so, while the caudal turns backward and then breaks up into a number of secondary rays presenting a peculiar conformation that is characteristic of all these forms in which the vermis presents a sinuous course. Ray C 1 appears as a relatively strong stalk arising from the base of ray C 2, not quite from the substance of the medullary mass itself, so that it cannot be considered as an independent branch, but must be considered as a part of lobulus C. This ray is separated from the succeeding ray by the fissura secunda. Ray B arises as two independent rays from the lower and caudal angle of the medullary substance. The lateral connections of these rays, however, show

clearly that they constitute a single subdivision, since they are connected with the end of the lobulus paramedianus and the beginning of an extensive parafloccular formation. Ray A is well developed and presents a large number of dorsal and ventral branches which, in the main, bifurcate at their extremities.

THE LOBULES

The lobulation of the arbor vitae is well organized, presenting a considerable degree of differentiation. Lobulus 1 is relatively extensive, consisting of two groups of folia. Lobulus 2 consists of two well developed subdivisions which are relatively richly foliated, the medullary rays being considerably subdivided. There is no lobulus 3. Lobulus 4 consists of two well defined divisions. These present a considerable number of folia, by far the greater number of which are hidden in the sulci. Lobulus C is subdivided into a rather extensive lobulus C 2, the caudal folia of which indicate the presence of a curve in the folial pattern and a lobulus C 1 which is narrow and contributes but little to the surface representation of the posterior lobe. Lobulus B is highly developed, being divided into two subsidiary lobules, which are richly subdivided and contribute very materially to the surface configuration of the posterior lobe. Lobulus A is well developed and consists of a considerable number of folia many of which lie in the fissure between lobuli A and B and also appear in the ventricular fastigium.

THE FOLIAL PATTERN OF MYRMECOPHAGA JUBATA

The folial pattern presents a considerable increase in organization as compared with the marsupial pattern. The fissura primaria is well defined and appears at about the middle of the median section of the folial pattern. It extends forward and outward presenting a somewhat sinuous course. The fissura secunda appears somewhat above its usual position on account of the increased development of lobuli B and A. Its continuation, outward, however, may be traced to the usual point of transition between the lobulus paramedianus and the lobulus paraflocculari.

Lobulus 1 consists of four vermal folia and two caudal folia which appear to be somewhat independent. Lobulus 2 presents a subdivision into two definite portions both of which present definite vermal and lateral components. The foliation is rather simple. Lobulus 4 presents a rather considerable increase in complexity. It begins with two or three folia which extend throughout the entire width of the lateral hemisphere. Succeeding these, however, the folia of lobulus 4 A become shorter and shorter, the last folia being quite short and chiefly vermal in character. Lobulus 4 B is made up of three simple folia, two of which extend almost the entire width of the lateral hemisphere. Only one of these three folia, however, finally reaches the periphery. Lobulus C is divided into two portions, C 1 and C 2. Lobulus C 2 presents a peculiar formation of the first two visible folia, which leave the vermis as two narrow lamellae, become considerably widened and then contract to give rise to two simple folia which extend to the periphery representing the lobulus simplex. The succeeding vermal folia of lobulus C 2 form a simple twist of only about half a turn, straightening out to become continuous with the folial chain of lobuli C 1, B and A. The twisted and straight portions of C 2 connect in the depths of the paramedian sulcus with the folia which form the ansiform lobule. The lobulus ansiformis succeeds directly on the folia forming the lobulus simplex, and consists of a group of shortening folia which pass laterally to form an apical transition from crus 1 into crus 2. Crus 1 and crus 2 produce a definite sulcus intercruralis. Crus 2 is succeeded by a straight paramedian formation possessing definite connections with

the vermal portion of lobulus C 2. Lobulus C 1 presents a few vermal folia connected with the terminal paramedian folia. Lobulus B consists of two groups of serial folia, diminishing and then expanding in width as lobulus B 1 proceeds caudally toward lobulus A. The peduncle of lobulus B shows a definite inclination downward and outward around the elbow formed by the bend of the lobulus paramedianus, and seems to implant itself into the medullary substance supporting the lobulus paraflocculuris. The lobulus paraflocculuris consists of a long chain of lamellae that are directly continuous with the paramedian chain, closely paralleling its course in the reverse direction. When the parafloccular chain reaches the apex of the lobulus ansiformis, it turns mesially, then laterally and finally caudally, forming a fairly definite lobulus petrosus with an uncus terminalis. Lobulus A consists of a diminishing group of folia that are connected together into a peduncle which is continued outward toward the general region of the lobulus flocculuris. The lobulus flocculuris appears in the usual position between the parafloccular formation and the cerebellar peduncle.

The medullary implantations of the various lobules show that lobulus 1 and the cephalic portion of lobulus 2 have separate implantations, while the caudal portions of lobulus 2 and lobulus 4 have a common implantation. The lobulus simplex, lobulus ansiformis and lobulus paramedianus rest on a broad foundation of medullary substance, while lateral to it and separated from it by the sulcus paraflocculuris, the parafloccular formation presents a long implantation into the medullary substance.

PHYSICAL CHARACTERISTICS OF MYRMECOPHAGA JUBATA

The great anteater is a large, bizarre-appearing animal varying in length from 4 to 7 feet. It is covered with stiff, bristly hair of considerable length, especially on the tail where it may be from 15 to 16 inches long. The head is elongated and narrow, the nose being considerably prolonged. The tongue is from 6 to 8 inches long, cylindric and extensible to a considerable distance. The eyes are anterolaterally placed and possess partially overlapping fields of vision; their movements are not extensively conjugated. The ears are diminutive. The neck is long and mobile. The body is large and heavy and the limbs are of moderate length, the hind limbs being larger than the fore limbs. The hind limbs serve chiefly for locomotion. The fore limbs are capable of a limited degree of unilateral independence and are used not only for locomotion, but also for tearing to pieces the ant-hills where the animal's food supply is found. The fore limbs are also an efficient means of defense. In walking, the anteater curves the claws inward, the weight being carried on the outer sides of the fore feet while the hind feet are plantigrade. It is not possessed of any degree of speed, its awkward progression being a sort of amble.

ELEPHAS ASIATICUS (ELEPHANT)

The arbor vitae of the Asiatic elephant provides a degree of foliation and subdivision that is rich even considering the complexity of the arbor vitae which is characteristic of the ungulate order. The primary divisions of the medullary substance are relatively complicated, and the secondary divisions exceed by far those found in any other of the ungulate group. The outline of the arbor vitae is more or less oval, the cephalo-caudad diameter exceeding the height of the cross-section. The fissura primaria lies in front of the median section of the arbor vitae almost directly opposite the approach of the ventricular fastigium to the medullary substance and is more or less curved, proceeding from before back-

ward and downward. The fissura primaria and the ventricular fastigium divide the arbor vitae into the anterior and posterior lobes. The amount of substance provided by the posterior lobe considerably surpasses that furnished by the anterior lobe, about two thirds of the sagittal section belonging to the posterior lobe. The fissura secunda is relatively high in the circumference of the posterior lobe, and, instead of being more or less horizontal, it is directed at a considerable

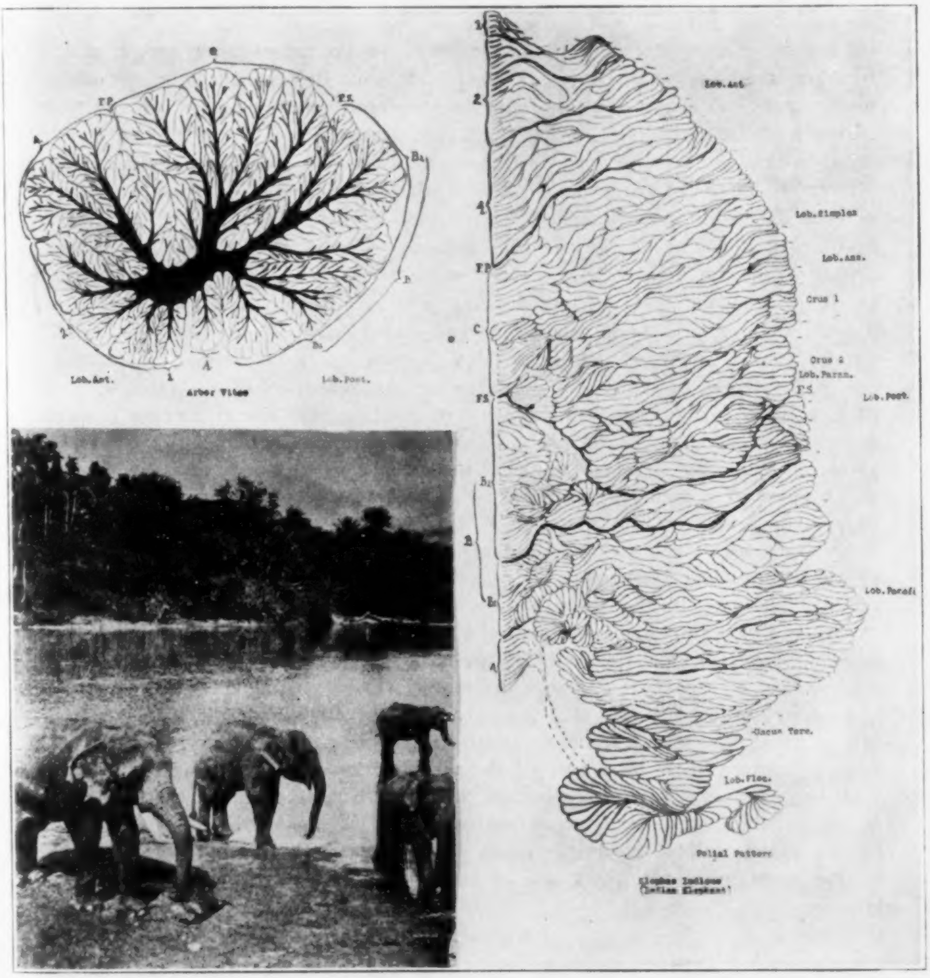

Fig. 7—Elephas indicus (Indian elephant).

angle from before upward and backward. The fastigium approaches the medullary substance at about its midpoint and is deep and narrow. The main mass of the medullary substance is situated at the junction between the anterior and posterior lobes. It presents a rather blunt extremity extending forward into the anterior lobe with a crescentic disposition in the posterior lobe, there being a marked drawing upward of the medullary substance into ray C and backward

into the rays forming lobulus B. All the chief branches of the medullary substance are heavy stemmed extensions from the medullary core, and they give rise to a profuse arborization.

THE MEDULLARY RAYS

Ray 1 is of considerable size in comparison with those of the other ungulates, and it arises cephalad to the ventricular fastigium as a single trunk which gives off a considerable number of side branches and terminates in a bifurcation. The second branch arises independently from the medullary substance, but it probably belongs with the succeeding rami, the entire group representing ray 2, which forms a large lobulus 2. Ray 2 consists of this small independent branch which divides and gives origin to a large number of lateral branches, and of an extension forward of the main mass of the medullary substance giving rise to two strong stems which proceed forward and upward giving off secondary divisions and bifurcating at their terminations. The uppermost of these is distinctly concave upward and is heavily branched at its point of bifurcation giving off lateral branches and ending in a three-fold division. Ray 4 is a thick, heavy stem, arising from the upper aspect of the main mass of the medullary substance, giving off cephalic branches and dividing into two strong stalks which proceed upward and forward, again subdividing and giving off numerous lateral branches. On its caudal aspect, ray 4 gives off a number of strong stems, particularly one in the depths of the fissura primaria, which forms part of the cephalic wall of this fissure. The medullary substance of the posterior lobe is concave upward and is continued backward into an ascending branch, forming ray C which gives off a number of small branches and then divides into a cephalic branch, which gives off a number of smaller twigs, and a large caudal branch, thick and heavy, which divides into three chief subdivisions. These subdivisions proceed upward and backward, giving off a large number of lateral twigs. In the depths of the fissura secunda, there is a strong branch near the base of ray C which is relatively heavy. In the folial pattern this branch gives rise to a paravermal extension which produces a cluster of folia. Ray B is a thick, prominent stem arising from the caudal extremity of the medullary core. It gives off two major subdivisions, an upper B 2 and a lower B 1, which subdivides into secondary and tertiary branches. Ray B 2 is extensive in the arbor vitae but much reduced in the folial pattern. It continues outward into a group of folia which forms what is apparently the first part of the paraflocculus. Ray B 1, although somewhat less extensive in the arbor pattern, has a much more extensive representation in the folial pattern, being connected with what is apparently the rest of the lobulus parafloccularis. Ray A consists of a relatively slender stalk arising close to the ventricular fastigium and proceeding ventrally, giving off secondary branches.

THE LOBULES

The lobules of the arbor vitae consist of the following: Lobulus 1 forms the cephalic boundary of the ventricular fastigium, and is composed of a number of close-set folia. Lobulus 2 appears as a triple lobulus consisting of an independent ray arising directly from the medullary substance, and two other groups of rays which arise from the main protrusion forward of the medullary substance, the dorsal ray being more extensive and divided into two portions. These lobules are all made up of a large number of secondary folia. Lobulus 4 is of moderate size and presents a number of deep branches and folia. It is composed of two chief groups of folia. The subsidiary subdivision is quite rich. Lobulus C is a relatively extensive lobulus consisting of a number of submerged groups of

folia and four major groups which appear on the vermal surface. The subdivision into folia is relatively rich; many of the folia show a vermal division which does not extend out into the lateral lobe when the folial pattern is examined. Lobulus B is extensive, being subdivisible into two portions, lobulus B 2 and lobulus B 1. In the arbor, lobulus B 2 is more extensive than lobulus B 1, but the reverse is true in the folial pattern. Lobulus B 2 consists of three definite subdivisions, the dorsal two belonging together, and the ventral being more independent. Lobulus B 1 is complicated, being composed of a dorsal branch which is extensively subdivided, and a less highly developed ventral portion. Lobulus A is simple in its composition, being formed by a single undivided ray which gives off lateral branches. It forms the caudal boundary of the fastigium.

THE FOLIAL PATTERN OF THE ASIATIC ELEPHANT

The folial pattern of the elephant is extremely complicated. Its mass is by far the greatest of any cerebellum studied, and the richness of its foliation and the subdivisions far exceed those of any other form. The foliation is relatively irregular, folia appearing at many divergent angles at almost any part of the surface and terminating by merging into other folia or disappearing. The arrangement of the folia at the lateral extremities of the hemispheres is similar in *Elephas* to that in *Cetacea* in that there is a fusion in the depths between preceding and succeeding lobules. In general, as might be expected from the richness of the arborization in the arbor vitae, the folia are much more extensive in the midline than in the hemisphere, except in lobulus C and the lobulus paraflocculáris, where the reverse is even more true; so that in the sum total the richness of foliation of the hemispheres exceeds that of the arbor vitae. All the lobules except C and B 1 show a tendency toward condensation as the periphery is approached. The most characteristic feature of the folial pattern of the Indian elephant is the consummation of the tendency which distinguishes the ungulate pattern, in the extrusion from the midline of a large number of folial rosets which are disposed in a paravermian position, and which may well be described as the paravermis. This phenomenon appears only in the lobules beginning with the caudal half of lobulus C. The cephalic portion of lobulus C shows relatively the same arrangement of folia as is seen in the lobules of the anterior lobe, which indicates its agreement with the principles concerned in the formation of the lobulus simplex. A large number of sulci which appear in the vermis pass out only for a short distance. The majority of the fissures separating these lobules tend to run forward as well as outward. The fissura primaria is well forward in the folial pattern and divides the cerebellum into unequal divisions, the anterior lobe occupying a subordinate position, perhaps one fifth of the entire surface of the lateral hemisphere, and being characterized by a fairly simple folial arrangement.

Lobulus 1 consists of a group of about five surface folia, all of which show an increasing tendency toward the formation of lateral extensions. All of the folia of lobulus 2 show vermal characteristics and also participate in the formation of the hemisphere. The lateral extensions become more and more developed with each succeeding folium. The majority of the folia of lobulus 2 show a number of vermal sulci which converge into one narrow and one broad folium, which as they pass out into the hemisphere, are subdivided by a considerable number of lateral sulci. The second portion of lobulus 2 shows an essentially similar arrangement, a large number of vermal folia undergoing a considerable reduction in number at the midpoint of the hemisphere and a return to numerous lateral folia at the

periphery. Lobulus 4 is a relatively simple lobulus, the folia of which are arranged more or less in parallel lines extending outward and converging on the periphery, the number of vermal folia being considerably reduced in the hemisphere. Lobulus C consists of two definite and distinctly differentiated portions. The cephalic portion shows an appearance similar to that seen in the anterior lobe, the folia being relatively simple, and the vermal portion presents practically no complications. At about the junction of the cephalic and middle thirds of lobulus C, however, both the vermis and the lateral portions begin to show a considerable degree of complexity; the vermis presents a reduplication, and many groups of vermal folia are extruded laterally forming a series of folial rosets lying along the paramedian sulcus which may well be termed the paravermis. The folia continuing outward from the vermis into the lateral hemisphere show an increasing degree of complexity, running at considerable angles. The great majority of the sulci run obliquely for only a short distance, disappearing into the fissures which limit the folial groups. Lobulus C shows a slight and abortive attempt to form an ansiform lobulus, there being only an unsatisfactory development of crus 1 and crus 2 and the intercrural sulcus. Following this irregular region there appears a group of folia which tend to arrange themselves serially from before backward and inward in the manner reminiscent of the formation of the lobulus paramedianus. Lobulus C is as usual bounded caudally by the fissura secunda. Lobulus B shows a definite division into cephalic and caudal portions. The cephalic portion is relatively extensive in the vermal region, producing an extremely complicated arrangement of the vermal rosets in the paramedian fissure, but rapidly constricting as it extends outward until its lateral extension is reduced to only five or six striplike folia which continue outward and finally are reduced to a few lamellae. The remainder of the lobulus represented by lobulus B 1 is considerably less extensive in the vermis, but much greater in the hemisphere. This portion of the lateral hemisphere of the cerebellum, corresponding with the termination of the paramedian formation and the entire paraflocculus, presents a complicated arrangement of folia, it being almost impossible to follow the definite folial chain arrangement which has been so easy to trace and so characteristic of the folial pattern of the less complicated cerebella. The vermis shows the extrusion into the paramedian region of large groups of folia, and the root of the paraflocculus shows the production of a large number of folial rosets which are continued outward into a series of folia which seem with some degree of complexity to follow one another in the usual chainlike arrangement. The paraflocculus gradually diminishes in size, the more cephalic lamellae being long narrow folia, constricts itself into what might be termed an uncus terminalis and terminates in close proximity to the lobulus floccularis which immediately succeeds it. Lobulus A is a simple group of folia forming a single roset which has a definite peduncle continued outward in the general direction of the lobulus floccularis. The lobulus floccularis follows directly on the uncus terminalis of the lobulus parafloccularis and is situated in the usual position between the peduncle of the cerebellum and the termination of the lobulus parafloccularis. It consists of a sinuous series of moderately long, thin lamellae which are disposed in a double S-shape, the terminal folia being drawn out into a narrow chain which terminates in a roset that returns on itself.

There is no definite arrangement for the peduncular implantation into the medullary substance. The entire development of the folia is so extensive that the medullary substance is tremendously increased, and the cerebellum is more or less evenly folded on itself along a simple furrow which is interposed between

the lateral extremity of the anterior lobe and the lobulus simplex cephalically, and the remainder of the posterior lobe caudally. The furrow separating these insertions of the lateral terminations of the folia seems to terminate at about the separation between the folia assigned to crus 1 and to crus 2.

PHYSICAL CHARACTERISTICS OF ELEPHAS ASIATICUS

The elephant is the largest of all living mammals with the exception of *Cetacea*. It possesses a large, massive head, the nose being continued forward into a long actively mobile trunk which is used to explore the environment. The trunk is also prehensile and is used to obtain food and drink. The eyes are located in the sides of the head and possess to only a limited extent overlapping fields of vision and but little motility. The ears are rather large and possess a considerable range of movement. The neck is relatively short and thick. The tongue is pointed and movable within the mouth. The tusks are used for offense, and defense and also to dig up food. The body is large and heavy as are also the legs. The hind legs serve chiefly for locomotion. The fore limbs are used not only for locomotion but also to a certain extent with unilateral independence. The limbs are remarkable in the length of the upper segment. The elephant proceeds by walking or running and is capable of a speed of about 20 miles an hour. The tail is small and insignificant.

CAMELUS BACTRIANUS (BACTRIAN CAMEL)

The arbor vitae of the camel presents the same voluminous character which is to be seen in the other ungulates. The foliation is rich, and the arborization extensive. The entire arbor vitae seems to be drawn out in the cephalocaudal diameter. The chief distinguishing character of the arbor vitae is the enormously developed extension of the medullary substance forming ray C, which presents this particular form on account of the fact that lobulus C consists of a complicated series of loops, the medullary substance being accumulated on the surface of the peduncle of the loop. The arbor vitae shows the usual division into anterior and posterior lobes. The identity of the fissura primaria is clearly indicated by the depth of the fissure and the configuration of the medullary substance. The fissure, however, is situated considerably caudal to the mid-transverse axis and approaches the fastigium of the fourth ventricle at a considerable angle. The fastigium is situated cephalad to the point of approximation of the fissura primaria. The fissura secunda is placed immediately behind a relatively small vermal lobulus C. The vermal portion of lobulus C is small on account of the fact that it presents an extensive curve, the major portion of the vermis being pushed outward to the right side and not appearing in the midline. Only a relatively inconsiderable part of lobulus C is represented in the median section. Lobulus B shows a considerable increase in size and also a marked lateral evagination to the right which, with the small size of lobulus C, seems to advance the fissura secunda more cephalad than is usual. The ventricular fastigium is relatively wide and comes into contact with the mass of the medullary substance at about a right angle.

The medullary substance is chiefly disposed as a large collected mass occupying the center of the anterior lobe and a long drawn-out tail which extends backward to form ray C. All the primary branches of the medullary substance are rather heavy and undergo secondary and tertiary divisions.

THE MEDULLARY RAYS

Ray 1 is relatively heavy, arising from the under part of the first portion of the medullary substance and presenting a stout cephalic branch immediately after its origin. Ray 2 arises as the cephalic prolongation of the medullary substance and consists of two chief branches which undergo considerable subdivision. Ray 4 divides into two rather definite groups, the first two forming lobulus 4 A. They consist of two fairly slender independent fasciculi which pass forward and upward from the dorsal prolongation of the medullary substance. Ray 4 B appears as a thick vertical branch, which rapidly divides into three subsidiary rays, and a long slender branch, which arises from the junction of the dorsal prolongation of the

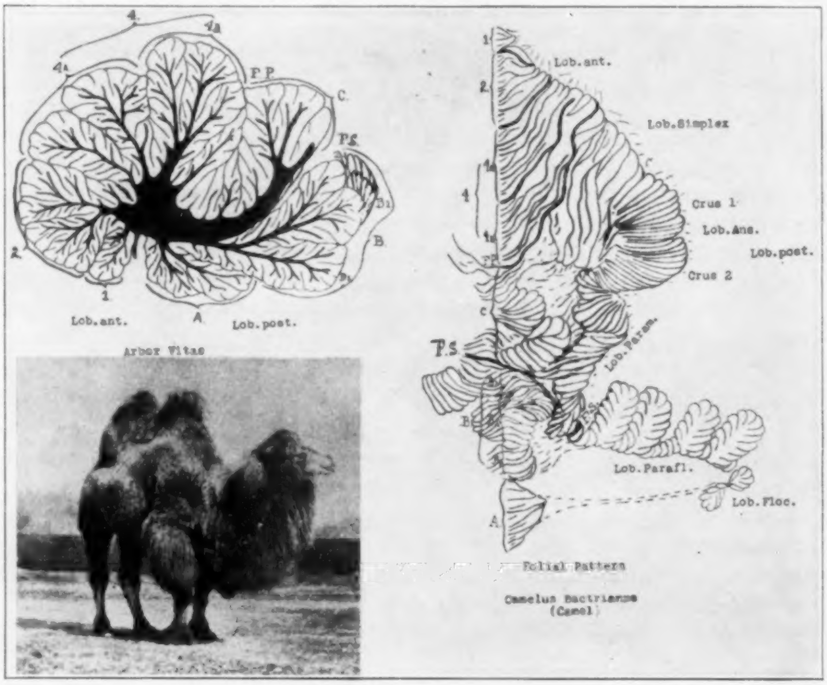

Fig. 8.—Camelus bacterianus (Bacterian camel).

medullary substance with the main mass. All these rays undergo a rather rich division, and the foliation of the lobulus is extensive and complex.

The mass of the medullary substance in the posterior lobe is relatively extensive but consists chiefly of a long drawn-out extension which forms the superficial core of lobulus C. The other medullary rays are relatively slender. From the concave upper surface of ray C there arise a number of elongated branches which lie in the depths of the fissura primaria. The summit of ray C divides into three main branches: the first two are situated more or less in the sagittal plane, the more cephalic giving rise to a number of twigs, while the third represents a transverse extension outward of the medullary substance as a peduncle for the remainder of the convoluted portion of lobulus C and presents the characteristic appearance of the medullary core of a twisted vermis. It is covered by a thin layer of cortical substance caudally. There is not much secondary division in

ray C. Ray B is a relatively stout fasciculus which divides almost immediately into two subdivisions. The dorsal one undergoes further subdivisions, so that there are three definite subdivisions of ray B, the most cephalic of which is relatively simple and lies chiefly in the midline, representing the median vermis. The second portion is rather complicated. It extends outward and forward in an imbricated series of folia presenting a double tier of folia overhanging the first branch of ray B. It is shown clearly in the folial pattern as a leaflike extension which is squeezed out from the midline and lies to the right of the midline. The most caudal division of ray B is a simple vermal formation which, however, again lies chiefly on the right side. It presents a series of bifurcated branches. Ray A is a heavy fasciculus arising from the under and cephalic extremity of the posterior medullary substance and immediately dividing into two branches which undergo secondary division.

THE LOBULES

The appearance of the arbor vitae indicating that the anterior lobe is more extensive than the posterior lobe is misleading, for the folial pattern shows that the vermis of the posterior lobe is much more extensive on account of the vermal reduplications which force the major portion of the vermis into a paravermian position and thus reduce the midline vermis. Lobulus 1 is a fairly well defined lobulus, cephalically limiting the fastigium, arising from a portion of the superior medullary velum and thus possessing some lingular characteristics. It presents one definite subdivision which lies in the sulcus between the first and second lobuli. The importance of this submerged branch is that it is continuous with a folium which extends outward and shows a definite lateral extension almost incorporating itself with the folia of the lobulus 2. Lobulus 2 is fairly extensive, presenting two major subdivisions and a series of minor subdivisions totalling five folial groups. Lobulus 4 is extensive, presenting two definite portions: a cephalic portion supported by two medullary rays and a caudal portion developed on one heavy ray which presents a number of surface reduplications forming the summit of the arboreal pattern and a number of subsidiary rays in the depths of the fissura primaria. Lobulus C is not extensive in the midline. Its cephalic portion is relatively simple and presents the usual crosscut appearance of the arbor, while its caudal portion presents a heavy extension of the medullary substance which indicates the function of this part of the medullary ray as a peduncle for the lateral extensions of the lobulus. Lobulus B presents three separate portions. The dorsal portion is relatively simple and is confined chiefly to the midline; a second portion shows a marked lateral extrusion in the paravermian region, and a third again returns to the midline and is relatively simple. Lobulus A is subdivided into two portions. It forms the caudal limit of the ventricular fastigium.

THE FOLIAL PATTERN OF CAMELUS BACTRIANUS

The pattern of the camel is complicated. The division of the folial pattern into anterior and posterior lobes shows a marked subservience of the cephalic group to the much increased mass of the caudal group of lobules. The anterior lobe shows an orderly arrangement of folia in parallel lines, with a definite vermal division characterized by short sulci passing out from the midline indicating a definite paravermial depression. The lateral extensions increase from before backward. The lateral folia are narrow and more numerous near the midline tending to decrease in number as the periphery of the hemisphere is approached. In general, all the lines of the anterior lobe tend to converge. The fissura primaria is an easily recognized fissure beginning at the midline

and presenting a rather sinuous course as it runs forward and outward toward the periphery. The posterior lobe shows a marked complexity in the organization of the vermis which is carried to such an extent that more of the vermis exists in a paravermian position than actually in the midline. The lateral extensions are prominent and present a rather complicated arrangement particularly in the region of the ansiform and paramedian formations. The fissura secunda is readily distinguishable between the vermal lobuli B and C, and appears in the lateral pattern at about the junction of the paramedian formation with the lobulus parafloccularis.

The first lobule consists of three vermal folia which converge into a definite independent peduncle, and a folium which arises from the depths of the fissure between the first and second lobuli and extends outward as a definite lateral extension, incorporating itself with the folia of the second lobulus. Lobulus 2 is relatively complicated. The sulci outlining the folia present a sinuous course. There are a number of short subsidiary vermal divisions. The lateral extensions increase in length from before backward and tend to converge into a single peduncle with which the lateral extension from lobulus 1 incorporates itself. There is a single medullary implantation for lobulus 2. Lobulus 4 presents a division into cephalic and caudal portions. The cephalic is rather more extensive from before backward, while the width of the caudal portion is greater. The same short sulci appear in the vermal region, indicating a definite vermis and a definite lateral expansion. The folia tend to converge, so that the extent of this lobulus in the periphery is considerably less than it is in the midline. The cephalic portion is continuous with the caudal portion at the periphery, there being a common folium belonging to both. There is a single medullary peduncle for the fourth lobulus. Lobulus C presents two definite portions, a simple vermal cephalic part and a convoluted paravermal caudal division. The first group of folia extends for only a short distance and then gives way to a formless large folium crossed by broken sulci emerging from the fissura primaria but soon returning to the depths of the same fissure. A number of fairly straight folia which extend outward and correspond to the lobulus simplex appear to be connected with this part of the cerebellum. The second paravermal portion of lobulus C consists of a marked curve to the right comprised of two groups of folia drawn together in a peduncle. The peduncle of the caudal part of this curve forms a definite mass and represents the broad medullary substance of ray C seen in cross-section in the caudal portion of lobulus C. The hemispheric part of lobulus C consists of a series of folia which are not directly continuous with the vermal folia, a wide area of almost bare medullary substance being interposed. This is crossed by a number of finely marked lines representing some attempt toward folial formation. The lateral folia consist of a number of fairly regularly disposed lamellae which succeed one another passing outward. These soon give way to a definite ansiform formation with a large number of short folia converging on a peduncle which is continuous with the bare mass of the medullary substance interposed between the vermis and the hemisphere. The lobulus ansiformis presents a definite crus 1 and a crus 2 which, before its transformation into the paramedian formation, presents a marked folial roset. The lobulus paramedianus, as it develops caudal to the roset marking the termination of crus 2, forms at once another roset made up of folia, the base of which is directed laterally—there then appear a number of narrow folia which are followed by a rather rapidly widening group of lamellae, the widest of which are insinuated into the depths of the fissura secunda and form the rudimentary folia which appear in the caudal aspect of ray C.

The lamellae narrow and form finally a fairly prominent roset which terminates the lobulus paramedianus. The caudal folia of crus 2 and the folia cephalad to the wide folia which disappear in the fissura secunda are connected with the vermal folia of lobulus C by means of the wide bare medullary area already mentioned. The group of folia in the middle of the lobulus paramedianus which is directly continuous with the vermal folia shows a similar formation on the left side of the vermis, which is continuous with the lower end of the paramedian formation of the left lateral lobe. Lobulus B is subdivided into three subsidiary portions, the first portion consisting of a group of folia which represent a curve of the vermis to the left and its return to the right. These folia then rather sharply turn to the left side of the vermis, and as suddenly return to the right, producing a marked folial roset which corresponds with the overhanging portion of lobulus B 2, as seen in the arbor vitae. The folial chain then gradually returns to the midline, representing the rest of the middle portion of lobulus B. The last portion of lobulus B is similar to the first portion and consists of a group of successive median folia which, however, are also disposed chiefly on the right side of the midline. All of the folia of lobulus B converge on a peduncle which tends to run outward in the usual position toward the base of the lobulus parafloccularis. The lobulus parafloccularis consists of a series of folial clusters rapidly succeeding one another and connected by only an insignificant number of short folia. This group of folial clusters occupies the usual position in the lateral hemisphere, ventral and lateral to the lobulus paramedianus and the lobulus ansiformis, extending well forward toward the origin of crus 1. There is no definite uncus terminalis and no lobulus petrosus. Lobulus A consists of a series of simple folia, symmetrically arranged and presenting vermal sulci without lateral extensions, which converge on a single peduncle. This peduncle runs out and fades away into the medullary substance more or less in the direction of the lobulus flocularis. The lobulus flocularis consists of a double group of folia which do not possess a visible connection with the lobulus parafloccularis. The lobulus flocularis appears in the usual position lying between the cerebellar peduncle and the paraflocular formation. The lobulus simplex, lobulus ansiformis and lobulus paramedianus find a broad insertion into the medullary substance by a series of implantations. The lobulus parafloccularis is based on the medullary substance lateral and ventral to the preceding lobules surrounding, to a certain extent, the insertion of the ansiform and paramedian formations.

PHYSICAL CHARACTERISTICS OF CAMELUS BACTRIANUS

The camel is an ungulate of considerable size, with a somewhat elongated body, four moderately long and slender legs, a long neck and a rather large head. The tongue is fairly long and quite mobile, and it is used to draw food into the mouth. The lips are large and fleshy, the upper being actively prehensile. The eyes are situated on the sides of the head and possess overlapping fields of vision only to a limited extent; they are only slightly mobile and are conjugated in their movements. The ears are small and rounded. The neck is long and freely mobile. The camel uses the mouth and teeth as means of defense or offense. It also will roll on its enemies if they are small. The limbs are used almost exclusively for locomotion, the particular footpad development adapting it to walking in sand. The body is large. The tail is small and inconspicuous. The gait of the camel is a slow shuffling walk or trot which can be increased to a lumbering awkward gallop. There is practically no unilateral independence of the fore or hind limbs.

RANGIFER TARANDUS (REINDEER)

The ungulates, in general, present a relatively similar type of cerebellar organization. The development of the cerebellum is particularly marked in the vermis which is extremely massive and presents a considerable degree of subdivision. The chief mass of the cerebellar organization is in the midline. The arbor vitae presents a complicated appearance, the lamellae being numerous and the medullary rays stoutly developed and presenting a considerable degree of secondary division and reduplication. The outline of the arbor vitae of the reindeer is more or less elongated and quadrilateral, the cephalic being somewhat more rounded than the caudal portion. The ventricular fastigium and

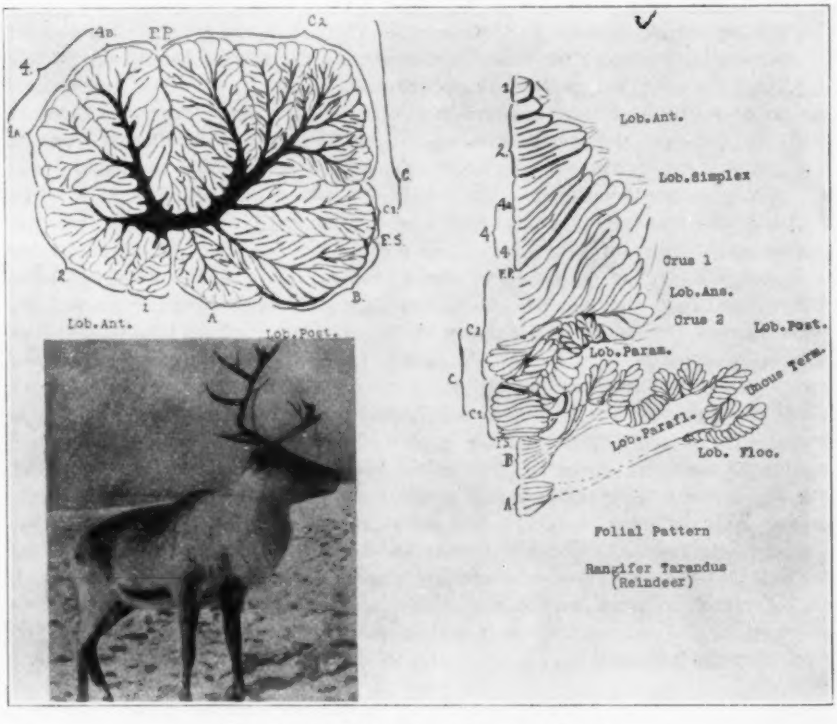

Fig. 9.—Rangifer tarandus (reindeer).

the fissura primaria are almost directly opposite one another. The fissura primaria is perpendicular, inclining slightly from before backward and downward. The ventricular fastigium is narrow and relatively deep. The anterior lobe occupies distinctly less of the surface of the arbor vitae than the posterior lobe. The fissura secunda appears low in the posterior lobe separating lobuli B and C, on account of the considerable increase in the complexity of lobulus C. The medullary substance presents a rather condensed protrusion forward into the anterior lobe and is drawn out caudally into a long, stout, well developed branch which turns upward into lobulus C, giving off successive branches as it proceeds backward and then turns upward. There is a relatively large number of submerged folia of considerable size, particularly in the depths of the fissura primaria.

THE MEDULLARY RAYS

Ray 1 has no definite origin from the medullary substance but appears more or less in the form of a lingular development. The successive medullary twigs appear not to originate in any definite stem but seem to arise from the superior medullary velum. Ray 2 is a conical prolongation of the medullary substance forward which gives rise to a series of branches on its ventral surface at right angles to the medullary mass, which present a fair degree of secondary division. The final stem of ray 2 is a direct prolongation forward of the medullary mass and divides into a terminal group of three subsidiary branches. There is no ray 3, although it is suggested by a submerged single folium arising near the base of ray 4. Ray 4 is a heavy stem arising at an angle from the medullary substance and directed forward and upward. At a considerable distance from its origin, it gives rise to a strong prolongation forward which rapidly subdivides forming a distinct subray 4 A. The rest of the ray continues upward, giving off lateral offshoots, and finally subdivides as it approaches the summit. There are a number of well developed slender rays along the caudal aspect of ray 4 B which form a group of folia submerged in the fissura primaria. This same arrangement of well developed submerged folia is found along the cephalic aspect of ray C 2. Ray C 2 is a large heavy ray and appears as a direct prolongation backward of the medullary substance of the posterior lobe. It gives origin, as already mentioned, to a number of slender rays whose folia are completely submerged in the depths of the fissura primaria. It continues backward and gives rise to a large, heavy ray which curves upward and forward, sending its subsidiary branches forward toward the fissura primaria. There is a large number of these cephalic and caudal subsidiary rays, the majority of which bifurcate at their extremities. Continuing upward and backward, ray C 2 then gives rise to a slender dorsal ray which is richly branched and presents a terminal subdivision. The terminal portion of ray C 2 continues backward into a gradually diminishing ray which sends branches upward and backward to form an apical spray, before doing which it gives rise on its caudal surface to two rather well developed rays which present in the arrangement of their ventral folia, particularly the lower one, the typical appearance shown by folia which are cut at an angle. These rays enter into the formation of the convoluted vermal folial arrangement characteristic of the caudal portion of ray C 2 and the beginning of ray C 1. The caudal aspect of the lower part of ray C 2 gives origin to one or two slender folia which serve to connect the convoluted folial pattern of one side with the folia of the other side. Ray C 1 arises near the base of ray C 2 as a slender dorsal branch, which gives rise to simple lateral branches and then bifurcates. Ray B is a long curved branch from the caudal angle of the medullary substance which presents numerous lateral outgrowths. Ray A is a relatively slender ray, which, however, is richly branched and presents a number of subsidiary folial groups.

THE LOBULES

Lobulus 1 presents a peculiar organization, not having a central ray, but it is provided with a number of slender twigs which appear to arise from the superior medullary velum. Its peripheral portion is considerably broader than its proximal origin from the medullary substance immediately adjacent to the ventricular fastigium. This arrangement may be considered to be a true lingula. Lobulus 2 arises on the basis of a number of medullary rays, the first two of which seem to spring by independent origin from the medullary substance. The medullary core extends forward to a conical termination which affords origin

for three subgroups of folia, the entire lobulus being made up of seven folial groups, the first and last being submerged from the surface, and the remaining five appearing on the surface. The junction of lobulus 2 with lobulus 4 presents an indentation as if produced by the mesencephalic collicular plate. Lobulus 4 is made up of two subsidiary groups produced by the division of ray 4 and presents a simple series of folia. Lobulus C is rich and extensive, being subdivided into a complicated lobulus C 2 and a simple lobulus C 1. Lobulus C 2 consists of two portions. Its cephalic portion is relatively simple corresponding with a similar simple arrangement in the folial pattern. Its caudal portion, however, made up of the complicated terminal efflorescence of ray C 2, is much more highly developed, and in its caudal division shows that the vermis is undergoing a series of twists from one side to the other. Lobulus C 1 is relatively narrow and simple in its organization, as the vermal twisting has ceased in this part of the cerebellum. Lobulus B is rather extensive and bulbous, the surface folia showing no complexity in arrangement. Lobulus A is, again, of a peculiar shape, expanding considerably and having a relatively simple surface expression.

THE FOLIAL PATTERN OF RANGIFER TARANDUS

The folial pattern of the reindeer shows the increasing predominance of the posterior lobe. The anterior lobe is relatively simple. The fissura primaria appears somewhat cephalad to the midpoint of the sagittal section, is directed markedly forward and outward and is relatively straight. The fissura secunda appears between the complicated convolutions of lobulus C and the relatively simple arrangement of lobuli B and A. It is continued laterally and limits the lobulus paramedianus at its junction with the parafloccular formation. Lobulus 1 presents a few vermal lamellae. Lobulus 2 consists of two relatively short lamellae which are succeeded by three parallel folia which are all subdivided in the vermal region and show distinct evidence of participation in the formation of the lateral mass. The folia of lobulus 4 are relatively simple in arrangement, being successive lamellae with a vermal differentiation, two, three or four folia joining to form a single folium as it approaches the lateral extremity of the hemisphere. Lobulus C presents a division into lobuli C 2 and C 1 which, again, are subject to considerable resubdivision. Lobulus C 2 presents a simple cephalic portion, consisting of parallel folia which extend from the mesial to the lateral limit of the hemisphere. There is a definite division between a vermal and a lateral portion. The most cephalic folia of C 2 represent the lobulus simplex. There are a number of shorter folia succeeding the lobulus simplex, followed by crus 1 of the lobulus ansiformis, a successive chain of shortening lamellae. Crus 1 forms a distinct apex, with the appearance of a short crus 2 and the production of a definite sulcus intercruralis. Before the transition into the lobulus paramedianus, the folial chain presents a double roset which is then succeeded by the regularly arranged folia of the lobulus paramedianus.

The vermal portion of lobulus C 2 connected with the lobulus ansiformis and the cephalic part of the paramedian formation shows a marked convolution. The lamellar chain begins on the right side of the vermis, but extends more and more to the left, the first turn of the sigmoid arrangement occurring practically entirely on the left side of the vermis. Following this, the lamellae return to the right side, creating a distinct S-shaped formation, with the second loop of the S entirely on the right side of the midline. The lamellae then approach the midline, extend partially into the left side of the vermis and then gradually return to the median position. The middle folia of C 1 come

into direct relationship with the terminal folia of the lobulus paramedianus. The caudal folia of lobulus C 1 are connected with the lobulus paramedianus by means of a peduncle. Lobulus B is a single roset with a peduncle which is continued outward toward the base of the lobulus parafloccularis. The lobulus parafloccularis appears as a direct continuation of the paramedian chain, almost at once developing a series of lamellar rosets. This chain of parafloccular rosets is continued around the under and outer surface of the lobulus ansiformis as far forward as the lobulus simplex. At this point, the chain turns on itself and returns along its proximal arm, terminating as a fairly well defined uncus terminalis. Lobulus A consists of a relatively simple roset, the peduncle being continued outward toward the termination of the lobulus flocculararis. The lobulus floccularis consists of a chain of lamellae, gradually increasing in size until it terminates in a roset.

The reindeer presents a lingula which possesses a lateral implantation that serves also for the most cephalic folium of lobulus 2. There is an independent peduncle for the remainder of lobulus 2 and also for lobulus 4. Lobulus C has a single broad implantation with the paraflocular implantation lateral and ventral to lobulus C.

PHYSICAL CHARACTERISTICS OF RANGIFER TARANDUS

The reindeer presents the typical form of the deer, being fairly heavily built, with four moderately short legs, a long neck, a good sized head and spreading antlers. The eyes are situated well forward in the head and have considerably overlapping visual fields. The movements of the eyes are well conjugated and present a considerable range of mobility. The tongue is large, fleshy and prehensile. The neck is fairly movable. The body is of medium weight and the legs are slender and rather short, with padded feet. The tail is almost nonexistent. The reindeer advances by walking, trotting and running. It is possessed of a considerable degree of speed but does not present any material agility or nimbleness. There is little unilateral independence in the use of its forefeet.

GIRAFFA CAMELOPARDALIS (GIRAFFE)

The pattern of the arbor vitae of the giraffe shows the extreme degree of differentiation and division which is typical of the ungulates. The arbor vitae is roughly quadrilateral in shape and presents a considerable notch in its cephalic border in which is lodged the collicular plate of the midbrain. The arbor vitae shows the usual differentiation into anterior and posterior lobes by the fissura primaria and the ventricular fastigium. The fissura primaria appears directed from above downward and somewhat forward, approaching almost directly the summit of the ventricular fastigium. The fastigium is a long narrow recess which extends upward to the medullary substance. The fissura secunda appears in its usual position between lobuli B and C, directed from before backward, and somewhat upward. The posterior lobe is considerably larger than the anterior lobe, while the fissura secunda divides the posterior lobe into a greater dorsal and a smaller ventral portion. The arrangement of the medullary substance in the center of the arbor vitae presents a U-shaped form, owing to the heavy character of rays 4 B and C 2. The rest of the medullary substance is situated in the center, that of the anterior lobe being relatively large and divided into two portions. One corresponds to the extension forward of the medullary substance, while the second is an upright stalk forming the base

for ray 4. The medullary substance of the posterior lobe is drawn out into a curved caudal extension which gives origin to the large rays forming lobuli C 1 and C 2. The arbor vitae is characterized by the extreme richness of subdivision, a large number of secondary and tertiary medullary branches arising from the chief divisions.

THE MEDULLARY RAYS

Ray 1 arises as a sort of lingular formation from the depths of the fastigium by a branch which springs from the junction of the superior medullary velum and the medullary substance, then frees itself from the former, forming an independent ray. The medullary rays of lobulus 2 form a series of separate inde-

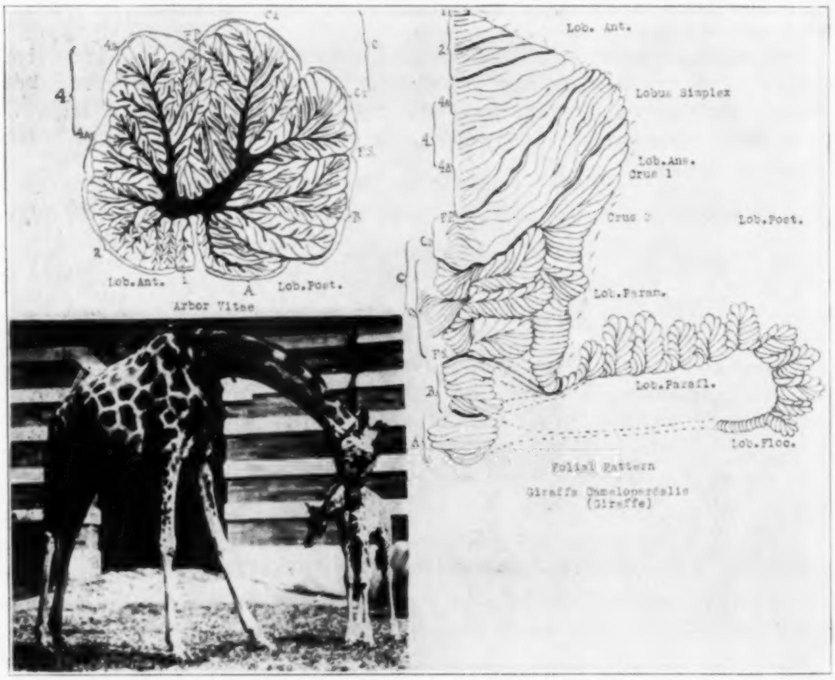

Fig. 10.—Giraffa camelopardalis (giraffe).

pendent stalks arising from the stubby cephalic projection of the medullary substance. These rays are three in number. The first is a simple stem giving off lateral branches. The second is thicker, gives off lateral stalks and is subdivided. A small submerged ray follows. The third stem, the largest of the three rays, appears as a direct continuation forward of the medullary substance and is a relatively thick stalk which divides into two main subdivisions which give off lateral branches and undergo further division. Ray 4 appears as a thick, heavy vertical extension of the medullary substance which immediately divides into two heavy rays, the cephalic extending forward and then subdividing to give origin to a number of smaller branches. Ray 4 B proceeds almost directly upward as a thick, heavy stem, giving off short cephalic branches and a longer stalk which somewhat overhangs lobulus 4 A. The termination of ray 4 B proceeds upward to divide into a spray of subsidiary branches. A considerable number of

long branches arise from the caudal aspect of ray 4 B and lie in the depths of the fissura primaria. These become simpler as the depths of the fissura primaria are approached, the uppermost showing a secondary subdivision; the second only lateral branches, and the third no branches at all. There are a number of short rays in the depths of the fissura primaria which apparently belong to the posterior lobe. Ray C arises as a thick heavy continuation upward and backward of the posterior medullary substance. It is large and gives off a series of rays situated in the depths of the fissura primaria, some of which are rather richly branched, and then divides into ray C 2 and ray C 1. Ray C 2 almost at once gives rise caudally to a long, curving plumelike ray and a thick, heavy vertical stalk cephalically, which then subdivides into a number of complicated branches. Ray C 1 proceeds backward as a relatively heavy ray, giving off lateral branches, and then subdivides in a manner characteristic of a considerable degree of convolution in the vermal pattern. In the fissura secunda are a number of subsidiary rays, one of which is of considerable size and apparently participates in the marked reduplication of the vermis. Ray B arises as a direct continuation backward of the posterior medullary substance, giving off a few short branches, and then subdivides into a dorsal and ventral branch, the former being quite complicated. Ray A arises from the medullary substance close to the fastigium, proceeding directly downward and then backward in a long curve, giving off a considerable number of short cephalic branches and a large number of long drawn-out caudal branches.

THE LOBULES

The lobules of the arbor vitae depend on the complicated medullary division. Lobulus 1 consists of a narrow group of folia attached at its base to the superior medullary velum. Lobulus 2 consists of three primary divisions which may be resolved into at least seven subsidiary surface lobules. The first is an undivided lobulus, the second divides into two while the third is composed of four sublobules. Lobulus 4 A shows the effect of the collicular plate of the midbrain in its external configuration and consists of two simple divisions. Lobulus 4 B presents the cephalic summit of the arbor vitae. It has a rather complicated arrangement, owing to the large size of the sublobules which form the upper part of the cephalic wall of the fissura primaria. Lobulus C is a voluminous lobe, many branches being hidden in the depths of the fissura primaria. It is subdivided into two portions, lobuli C 2 and C 1. The caudal portion of lobulus C 2 presents a long plumelike lobulus already mentioned in the depths of the sulcus between lobuli C 2 and C 1, participating in the formation of the lateral swing of the folia into the left side of the vermis. Lobulus C 1 presents the usual appearance of a lobulus sectioned while in the process of a twist or turn in the formation of the vermal folial pattern. Lobulus B consists of a larger dorsal portion and a simpler ventral division. In the depths of the fissura secunda appear a number of subsidiary folia which participate in the swing of the vermal chain to either one or the other side. Lobulus A presents a peculiar long drawn-out appearance with a large number of folia which are hidden in the depths of the fissure separating lobuli A and B.

THE FOLIAL PATTERN OF GIRAFFA CAMELOPARDALIS

The folial pattern of the giraffe shows a marked difference in the anterior and posterior lobes. It also presents a well defined lobulus simplex. The anterior lobe is relatively simple in its arrangement, the fissura primaria appearing cephalad to the midpoint of the folial pattern and presenting a rather wavy course

outward and forward. The mesial extent of the anterior lobe is much greater than the lateral extent. The fissura secunda appears in the usual position between lobuli B and C and serves to mark off the extremely convoluted portion of lobulus C from the simple vermal pattern of lobulus B. It is continued outward and limits caudally the lobulus paramedianus. Lobulus 1 is a simple vermal lobulus. Lobulus 2 is divided on the surface into two subdivisions, the cephalic portion corresponding to the first two stalks and the caudal portion to the rather large third ray forming the major part of lobulus 2. The lateral extensions progressively increase in length. The folia show a definite vermal subdivision by short sulci which proceed outward for a variable distance. Lobulus 4 presents a distinctly triangular appearance and, together with the other lobuli of the anterior lobe, forms an almost perfect triangle. The cephalic folia forming lobulus 4 A are simply arranged and extend from the median line to the periphery. They are wide folia presenting short vermal sulci. The succeeding folia show a variable degree of lateral extent. The cephalic group begins with four separate folia and concludes as a single folium. The sulci extend for a variable distance into the hemisphere. There then succeeds a group of convergent, short folia, forming the median portion of this lobule, and then a single caudal folium which extends throughout the entire breadth of the anterior lobe. Lobulus C is subdivided into two very different portions. The cephalic division of lobulus C 2 presents a simple arrangement of vermal folia which continue outward as a series of long folia which, in general, are somewhat concave forward and tend to converge on the fissura primaria. These represent the emergence of the folia which were seen in the depths of the fissura primaria. There is a considerable reduplication of the folia forming the lateral portion of the lobulus. There is also a considerable number of vermal sulci. The caudal portion of lobulus C presents a high degree of vermal reduplication which has the peculiar characteristic of being limited almost entirely to the right half of the vermis. The lamellar chain presents three definite wide swinging extensions into a paravermian position, the mesial loops being continued over into the left side of the vermis and producing two small limited folial groups. The middle one of these three right lateral vermal loops shows a continuation outward into a folial roset which interrupts the orderly course of the lobulus paramedianus. On the left side of the vermis a structure somewhat similar to this roset appears, a series of folia which are continuous cephalically and caudally with the left lobulus paramedianus. The lateral portion of lobulus C 2 presents a lobulus ansiformis with a fairly well defined crus 1 and crus 2. Crus 2 is continuous caudally with a group of folia which is connected with the first of the right lateral vermal loops. It is then interrupted by the roset which is projected outward from the paravermian region into the paramedian formation. The roset is continuous by means of its peduncle with the cephalic portion of the second of the vermal loops. This roset is then continued caudally as the remainder of the lobulus paramedianus, connected both directly and in the depths with the third lateral loop of vermal C 1.

Lobulus B consists of a series of folia which caudally presents slight lateral reduplication. These folia are gathered into a distinct peduncle parallel with the fissura secunda, passing to the base of the lobulus parafloccularis. The lobulus parafloccularis is a direct continuation of the folial chain forming the lobulus paramedianus and arises as a short string of folia which is succeeded by a series of folial rosets varying in size and complexity. This row of folial rosets continues forward and outward along the lateral aspect of the lobulus paramedianus, crus 2 and crus 1, to the caudal limit of the lobulus simplex, where the chain of rosets turns on itself outward and then backward to terminate in a

roset. Lobulus A consists of a series of vermal folia forming a roset which sends its peduncle outward in the general direction of the lobulus floccularis. The lobulus floccularis is a direct continuation of the lobulus parafloccularis. It presents a single roset and a terminal group of folia. It is situated in the usual position between the peduncle of the cerebellum and the parafloccular formation.

The implantation of the folia in the medullary substance shows that the first and second lobuli are inserted together. The fourth lobule has an implantation which becomes continuous with that of the lobulus simplex, the lobulus ansiformis and the lobulus paramedianus. The lobulus parafloccularis is based on a broad implantation into the medullary substance ventral and lateral to the main mass of the anterior and posterior lobes.

PHYSICAL CHARACTERISTICS OF GIRAFFA CAMELOPARDALIS

The giraffe is the tallest of all the mammals, reaching a height of 20 feet. The body is of moderate size; the legs are long, slender and powerful, the fore limbs being somewhat longer than the hind limbs and thus raising the body higher at the shoulder than at the rump. The neck is long and tapering, and is surmounted by a rather small head. The eyes are laterally placed but look considerably forward so that there is a definite overlapping of the visual fields. The movements of the eyes are conjugated and with an apparently considerable range of mobility. The ears are elongated, tapering and actively movable. The upper lip is moderately elongated and prehensile. The tongue is about 18 inches in length, is actively prehensile and is used to drag leaves, twigs and branches into the mouth. The neck is long and mobile, and the giraffe is extremely accurate and agile in the movements of the neck in going at full speed through trees and underbrush. The gait is that of a pacing horse; it is awkward in appearance but of about the same speed as that of a good horse. There is but little unilateral independence of the limbs. The tail is quite long but does not possess any special function.

BOS (CALF)

The arbor vitae of the calf is relatively extensive and presents a mass of subsidiary branching and foliation which is relatively more extensive than that found in other ungulate cerebella of the same size. The caudal extension of the medullary substance in the posterior lobe is typical of the ungulate group. The fissura primaria appears in the vertical position and is situated directly opposite the fastigial recess which is wide open, these two structures together dividing the arbor vitae of the cerebellum into the anterior and posterior lobes, the latter being considerably larger than the former. The fissura secunda appears in the usual position between lobuli B and C. It divides the posterior lobe into a much more extensive dorsal and a much less extensive ventral portion. The ventricular fastigium is situated about the midpoint of the ventral portion of the cerebellum and is relatively wide open, but becomes reduced to the usual width as it approaches the medullary substance.

The medullary substance presents a U-shaped disposition, with a well marked condensation in the center of the anterior lobe, from which passes vertically a heavy ray 4, while there is a long drawn-out extension which proceeds upward and backward into lobulus C as the main core for the posterior lobe.

THE MEDULLARY RAYS

The first branch from the medullary substance, except a small inconsequential nubbin, is a slender stalk arising a short distance in front of the fastigial recess

and giving off side branches. The medullary rays forming the second group consist of a single stout extension forward and downward which immediately subdivides into two subsidiary branches which again undergo considerable rapid division. Ray 3 appears at the junction of the second and fourth medullary rays with the anterior medullary substance. If the independence of this ray should be questioned, it undoubtedly should be assigned to lobulus 2, on account of the lamellar arrangement found in the folial pattern. It is a slender ray giving off side branches and dividing into two main subdivisions at its summit. Ray 4 is a heavy prolongation upward and forward of the medullary substance, is thick and gives off a number of small subsidiary branches before it divides into its terminal group. The terminal group consists of three chief branches: a cephalic, which again divides into two well defined stalks; a dorsal, which presents side branches and a terminal division and a caudal, which

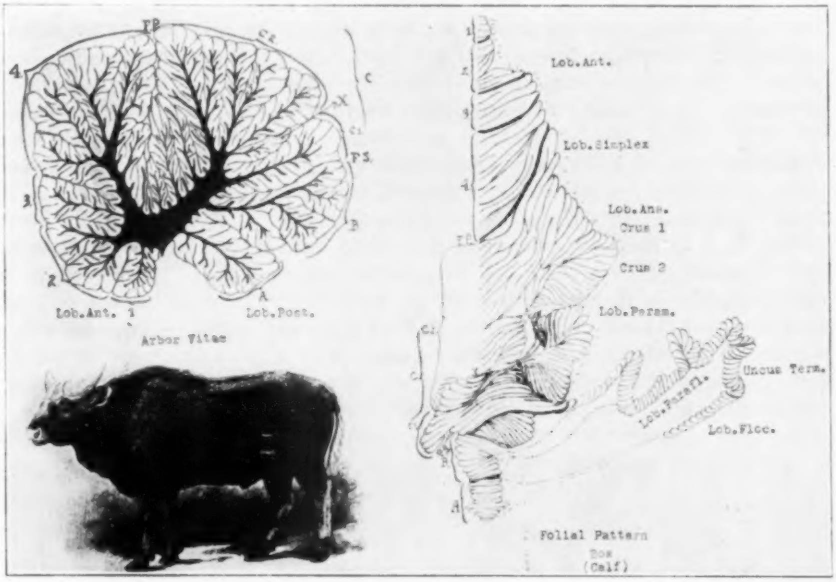

Fig. 11.—Bos (calf).

is more slender and undergoes less extensive division. There then arises from the caudal aspect of the stem of ray 4 a series of twigs which are hidden in the depths of the fissura primaria. The posterior medullary substance is drawn out into a thick, heavy prolongation upward and backward, and presents on its concave dorsal surface a number of rather extensively divided stalks which arise in the depth of and from the caudal boundary of the fissura primaria. The end of ray C divides into two chief subdivisions: (1) a heavy dorsal stem, which again divides into three chief branches, that in turn subdivide to produce an extensive lobulus C 2, and (2) a direct caudal extension of the posterior medullary substance which is drawn out into a long slender ray C 1 that sends out many side branches and then divides at its summit into a spray of rays which support a series of relatively wide folia. In the depths of the fissure separating lobuli C 1 and C 2 is a twig which arises from the base of ray C 1 and is of importance on account of the fact that it represents a connection

in the arbor of a group of folia which appear in the lateral folial chain between crus 2 and the paramedian formation. Ray B arises from the caudoventral aspect of the posterior medullary substance and presents a series of ventral branches of sufficient size to produce a series of sublobules on the ventral aspect of lobulus B. Ray A is a slender stem presenting side branches most of which undergo secondary division.

THE LOBULES

Lobulus 1 forms the cephalic limit of the ventricular fastigium and is a relatively well developed lobulus. Lobulus 2 and lobulus 3 may be grouped together as the usual arrangement found in the ungulates, but on account of the fact that ray 3 has an entirely independent origin from the medullary substance, it is given an identity of its own. Lobulus 4 is relatively extensive, and forms the cephalodorsal angle of the anterior lobe and the cephalic boundary of the fissura primaria. It presents a grouping of folia which might warrant a division into lobuli 4 A and 4 B. On its caudal aspect it shows a number of compressed folia which extend only for a short distance laterally and can be seen in the folial pattern only if the fissura primaria is opened up. Lobulus C is divided into an extensive C 2 which presents an extensive degree of subdivision. There are a number of submerged folia in the depths of the fissura primaria which have only a limited participation in the folial pattern and are succeeded by an extensive group which appears on the surface and forms the chief mass of lobulus C 2. At the termination of lobulus C 2 in the depths of the fissure between it and lobulus C 1, there is a group of folia which is important on account of the fact that it connects laterally with the peduncle of a distinct roset which participates in the production of the paramedian formation. Lobulus C 1 is not extensive and presents on its surface only a small number of laminae. Lobulus B is relatively compressed at its origin but expands at the periphery into three groups of folia. The most dorsal group is rather irregular and may be divided into two subgroups which, in the folial pattern, are seen to be implicated in a transposition of the folial chain from one side to the other. The two other more caudal groups are simple and represent the serial arrangement of two groups of folia. Lobulus A forms the caudal limit of the ventricular fastigium. It is a relatively simple lobulus, although it is of considerable size, and some of its branches are moderately subdivided.

THE FOLIAL PATTERN OF BOS

The folial pattern of the calf shows an arrangement similar to that seen in the other ungulates in its division into anterior and posterior lobes by the fissura primaria. The lines, however, are considerably straighter and less tortuous, and the folia are, in general, arranged in a more parallel manner. This may be due to the possible immaturity of the animal. The fissura primaria is situated somewhat in front of the midpoint of the folial pattern and extends out as a relatively simple straight sulcus toward the periphery. The anterior lobe is considerably less in extent than the posterior lobe, and the folia are arranged in a more regular fashion extending outward. There is less indication of a vermal portion, the vermal sulci being less pronounced and showing but little tendency to form a paramedian furrow. The fissura secunda appears as usual between lobuli B and C and is connected with the termination of the paramedian formation. Lobulus 1 consists of a group of vermal folia which shows some convergence, being implanted by means of a single peduncle. Lobulus 2 is divided into two portions—a cephalic vermal, and a caudal division.

If lobulus 3 is grouped with lobulus 2, this differentiation between the cephalic and caudal portions of the combined lobules becomes more marked. Lobuli 2 and 3 are implanted by a more or less common peduncle into the medullary substance. Lobulus 4 is fairly extensive in the vermis but much reduced in the hemisphere owing to the fact that many of the folia fail to reach the periphery, six chief folia being reduced to three.* At its caudal portion is the group of folia in the depths of the fissura primaria which has been noted in the arbor vitae. Lobulus C is divided into a much more extensive cephalic portion, lobulus C 2, and a much reduced caudal portion lobulus C 1. The cephalic portion is again subdivided. The cephalic part consists of a fairly regular group of lamellae, the lobulus simplex, which runs toward the periphery, bending forward and being reduced in size as it approaches the periphery of the hemisphere. There is a definite division into vermal and lateral portions, with the indication of a paramedian furrow. The caudal vermal portion of the cephalic subdivision of lobulus C 2 shows the beginning of a loop, the folia being arranged chiefly on the right side of the vermis. As the folial chain is followed, a swing over to the left side of the vermis occurs. The folia of the caudal vermal portion of lobulus C 2 then are succeeded by the lamellar chain of lobulus C 1 which is wide and crosses the midline with the loop first on the left side and then on the right side of the midline. These folia are continued out on either side to become directly continuous with the most caudal of the paramedian folia. The hemispheral portion of lobulus C presents the usual fairly simple arrangement in the cephalic portion corresponding with the lobulus simplex. As these lamellae shorten, crus 1 of the ansiform formation appears and rapidly extends outward with shortening folia, forms its apex and then turns back and inward as crus 2, producing a distinct intercrural sulcus with a number of simple folia interposed between the caudal extremity of crus 2 and the succeeding folia, which form a roset and are connected with the submerged group of folia in the sulcus between lobulus C 2 and lobulus C 1. This twists outward with the formation of a cluster of folia and ushers in the paramedian formation, a characteristic interpolation between crus 2 and the lobulus paramedianus of the ungulates. The paramedian formation then appears as a series of wide folia which proceed caudally and then form a caudal elbow, the folia rapidly diminishing in width to become continuous with a series of wide vermal folia representing lobulus C 1. Lobulus C 1 presents an extensive lateral disposition, the vermal folia being directly continuous with the lateral folia forming the caudal termination of the lobulus paramedianus as it approaches the lobulus parafloccularis. Lobulus B shows a rather thick twist of considerable extent, the folia converging in a large cluster formation which is situated to the right of the midline. The rest of lobulus B lies in the midline, although more to the left. A peduncle forms from the two parts of lobulus B which can be traced outward in the direction of lobulus parafloccularis. The lobulus parafloccularis begins as a series of folia directly continuous with the folia forming the lateral extension of lobulus C 1. This group continues outward forming a series of loose clusters not nearly so extensive as those of *Camelus.* The paraflocculus continues forward around crus 1 turning inward completely to surround crus 1, then turns backward and outward, and then inward again to terminate in a distinct uncus terminalis along the under surface of the first portion of the lobulus parafloccularis. Lobulus A consists of a simple group of folia arising from a single peduncle which may be traced outward a short distance but loses itself in the medullary substance, but in the general direction of the lobulus flocculari. The

lobulus floccularis consists of a simple cluster of folia in close relationship with the termination of the uncus terminalis succeeded by a diminishing chain of lamellae which continues inward toward the vermal portion of the cerebellum. The lobulus floccularis occupies its usual position between the peduncle of the cerebellum and the parafloccular formation.

The main mass of the posterior lobe is inserted in the medullary substance by means of a broad attachment supporting the lobuli simplex, ansiformis and paramedianus, while the lobulus parafloccularis finds an attachment to the medullary substance which is in the usual position lateral and ventral to the mass formed by the ansiform and paramedian formations.

PHYSICAL CHARACTERISTICS OF BOS TAURUS

The cow is a relatively heavy bodied ungulate. The legs are rather short, the fore limbs being somewhat shorter than the hind limbs, so that the animal slopes somewhat from his rump to his shoulder. The neck is short and thick. The head is heavy. The eyes are placed in the lateral surface of the head but have a considerable overlap in the visual fields. They are possessed of conjugate movement. The lips are somewhat prehensile. The tongue is thick and is actively mobile. The neck is possessed of a fair range of movement. The limbs are almost entirely for the purpose of locomotion, and possess but little unilateral independence. The tail is long and is used only to keep the animal free from flies. The cow is not possessed of much speed, and is rather slow and awkward in its movements.

MANATUS AMERICANUS (MANATEE)

The arbor vitae of the manatee is distinctly oval in outline, the horizontal being greater than the vertical diameter. It is much simpler than the ungulate cerebellum, the pattern being relatively coarse, with only a small degree of foliation. It is divided into approximately equal anterior and posterior lobes by means of the fissura primaria and the ventricular fastigium. The fissura primaria is situated behind the middle of the arbor vitae and proceeds forward and downward toward the fastigium. The fissura secunda appears in its usual position between lobuli B and C. It is situated somewhat above the level of the medullary substance and proceeds backward and slightly downward, dividing the posterior lobe into a much larger dorsal and a much smaller ventral portion. The medullary substance is disposed in a rather irregular manner. It presents a large mass in the center of the anterior lobe with a heavy extension upward forming ray 4. The medullary substance presents a constriction at the point where the fissura primaria approaches the fastigium, and is continued into the posterior lobe as a long caudal stalk which is continuous with ray C.

THE MEDULLARY RAYS

Ray 1 is a slender, undivided branch from the ventral aspect of the anterior medullary substance. Ray 2 arises as a sample direct extension forward of the medullary substance, giving off lateral branches. Ray 4 arises as a heavy upward prolongation of the entire medullary mass. It gives off a heavy stalk cephalically, ray 4 A, which gives off lateral branches and subdivides. The continuation of ray 4 proceeds upward as a thick, heavy stalk, ray 4 B, giving off rather simple side branches, and then divides into three terminal branches, the first of which proceeds forward and forms a simple folial cluster, the second upward with a restricted division and the third backward. Ray C arises as a direct

caudal prolongation of the posterior medullary substance, proceeding backward and upward, and divides into ray C 1 and ray C 2. Ray C 2 continues upward in a rather concave direction, and divides into a vertical and a horizontal division, the latter being somewhat more extensive than the former. Ray C 1 proceeds directly backward, giving off lateral twigs, and subdivides into two terminal branches. Ray B arises from the under surface of the caudal continuation of the posterior medullary substance, as a thick branch which divides into a caudal horizontal branch which gives rise to a number of secondary twigs and a ventral stem which is quite short. Ray A appears as a slender stem from the under surface of the posterior medullary substance, giving off lateral branches.

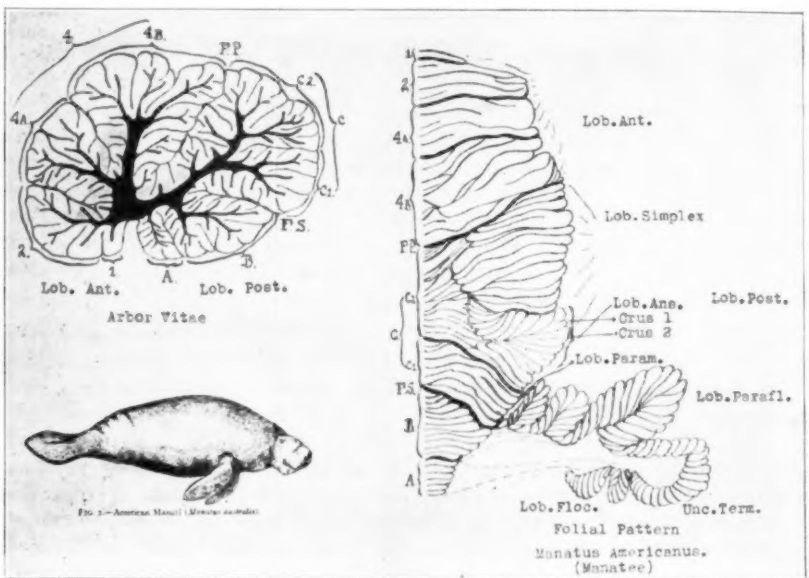

Fig. 12.—Manatus americanus (manatee).

THE LOBULES

Lobulus 1 appears as a single folium forming the cephalic margin of the fastigium. Lobulus 2 appears as a simple lobulus made up of rather coarse folia. Lobulus 4 is divided into two lobules, lobulus 4 A and lobulus 4 B. Lobulus 4 A forms the cephalic subdivision of lobulus 4 and consists of a few coarse folia. Lobulus 4 B is much more extensive and forms the summit of the anterior lobe. It is made up of a number of coarse folia, which may be rather irregularly arranged into three sets of folia. Lobulus C is divided into lobulus C 2 and lobulus C 1. Lobulus C 2 forms the caudal boundary of the fissura primaria. It is not extensive and is made up of a number of coarse folia, the caudal folia being slightly more numerous. Lobulus C 1 is a simple lobule, forming the caudal portion of lobulus C. Lobulus B is a rather large lobule made up of coarse folia distinctly subdivided into two portions. Lobulus A is a simple lobulus forming the caudal margin of the fastigium.

THE FOLIAL PATTERN OF MANATUS AMERICANUS

In general, the folial pattern is relatively simple. The folia pursue a fairly regular lateral direction. All the fissures and sulci are more or less parallel except in the caudal portion of lobulus C 2. There is no marked expansion laterally of the folial pattern at any point, the periphery of the folia showing a more regular outline than that found in any cerebellum except that of *Bradypus tridactylus*. The fissura primaria appears at about the middle of the arbor and proceeds almost directly outward with only a slight inclination forward. The fissura secunda appears in its usual position between lobuli B and C. It proceeds outward and somewhat backward, forming the apparent limitation between the paramedian formation and lobulus parafloccularis. Lobulus 1 consists of a single vermal folium. Lobulus 2 consists of three folia presenting a few vermal sulci and a single independent lateral sulcus dividing the middle folium. The folia of lobulus 2 are continued into a definite lateral portion. Lobulus 4 A consists of a wide cephalic folium subdivided mesially by vermal sulci and partially divided at the periphery. The caudal folium of lobulus 4 A presents a vermal sulcus with a tapering lateral extension. Lobulus 4 B presents a number of cephalic folia which converge on the sulcus separating lobulus 4 A from lobulus 4 B. Succeeding this is a relatively wide folium, proceeding forward and outward reaching the periphery. The succeeding folia are irregular and show vermal divisions and lateral portions. The sulci seems to show a tendency to wander aimlessly across the folia, many of them joining together. A considerable degree of reduplication appears in the most caudal folium at the periphery. Lobulus C is divided into two portions, lobulus C 2 and lobulus C 1. Lobulus C 2 presents a distinct differentiation into vermal and lateral portions. The vermal folia are narrow, irregular and tend to run forward converging on the fissura primaria. In the middle of lobulus C 2, they become somewhat more regular and are apparently continuous with the lateral chain of folia. In the caudal portion of the vermis, the folia of lobulus C 2 have a regular arrangement and are continued outward and backward into a peduncle which joins the caudal portion of the lateral folial chain. The lateral folial chain presents a simple arrangement of serial folia in the cephalic portion of lobulus C 2. This may represent an indefinite lobulus simplex. The chain continues backward as a series of relatively wide folia, and in its caudal third presents a distinct roset which may be recognized as the lobulus ansiformis, with a crus 1 and a crus 2 forming the sulcus intercruralis. Lobulus C 1 presents in its cephalic portion a number of vermal folia which run forward into the sulcus between lobulus C 1 and lobulus C 2. The caudal folia of lobulus C 1 arrange themselves in more or less parallel strips, running outward and backward, and are continuous with the folia of the lateral chain which now appear as undivided strips extending from the midline to the periphery. The folia at the periphery represent the lobulus paramedianus. Lobulus B appears as a group of folia increasing in width to an apex and then diminishing in a regular series. These folia produce a roset, the peduncle of which proceeds outward and is apparently continuous with the base of the lobulus parafloccularis. The lobulus paraflocccularis appears as a continuation of the folial chain of the lobulus paramedianus, into the parafloccular formation. The paraflocculus appears as a series of folial rosets, small at the beginning and becoming much larger, applied to the lateral surface of the lobulus paramedianus and the lobulus ansiformis as far forward as the fissura primaria, then returning in a rather irregular series of rosets and loops forming a definite uncus terminalis. Lobulus A presents a simple series of diminishing vermal folia, connected by means of a peduncle with the

lobulus flocculari. The lobulus floccularis appears as a continuation of the lobulus paraflocculari, beginning as a roset, and then showing an increasing and next a diminishing folial chain. It is situated between the peduncle of the cerebellum and the parafloccular formation.

The lobules and the folia are implanted in a rather simple manner into the medullary substance. The lobules of the anterior lobe tend to converge on a single broad implantation into the medullary substance, while a similar course is followed by the lobulus of the posterior lobe. The parafloccular formation is inserted by means of a broad base into the medullary substance, lateral and ventral to the rest of the posterior lobe.

PHYSICAL CHARACTERISTICS OF MANATUS AMERICANUS

The manatee represents *Sirenia.* Its present degenerated physical condition is due to its specialized adaptation to an aquatic habitat and a herbivorous dietary. The body, about 8 feet in length, is essentially fishlike, the neck having gradually shortened and externally disappeared. The eyes are small, with imperfect eyelids and a nictitating membrane. The lips are extraordinarily modified, the upper lip being divided by a wide groove into two mobile, swollen pads which are prehensile and, without the aid of the lower lips, can draw food into the mouths. The fore flipper is oval; it is capable of free movement at the shoulder, elbow and wrist joints and bears three vestigial finger-nails near the tip. The tail is flattened, sharply rounded off behind and not notched. The hind limbs have completely disappeared externally.

PHOCAENA COMMUNIS (PORPOISE)

The arbor vitae of the aquatic mammals belonging to the cetacean group offer extreme difficulties in a determination of the identity of the various lobes, lobules and fissures. From the form of the arbor vitae and the general distribution of the branches of the medullary rays, it is impossible to determine the exact position of the various fissures, and, therefore, the task of dividing the arbor vitae into the various lobules is almost impossible. A careful study of the arbor vitae, together with its connections with the folial pattern, indicates certain relationships which make it possible tentatively to divide the arbor vitae according to the scheme which has already been followed. The arbor vitae of *Phocaena* can be analyzed by first establishing the connections of the flocculus, paraflocculus and what would correspond with the lateral extension of lobulus C. According to this method, the posterior lobe apparently consists of a peculiar, distorted folial growth which appears collected in the caudal portion of the arbor vitae and consists of two peculiar medullary rays which are practically devoid of cortical covering, but are found to be continuous with an enormous expansion in the hemisphere and seem to combine the lobulus ansiformis and the lobulus paramedianus. If this demarcation is correct, the remainder of the foliated rays belong to the anterior lobe. The further allocation of the anterior rays into the lobules indicated appears to be warranted by a study of the connections of the foliated portions of the hemisphere with the various lobules of the arbor vitae. The arbor vitae itself does not supply any definite idea as to the identity of the various rays and lobules. Assuming that this arrangement is correct, which is not at all firmly established, the fissura primaria appears to be a small fissure separating the large medullary rays which form a corona around the ventral, cephalic and dorsal surfaces of the arbor vitae from a series of peculiar structures which have but little representation in the arbor vitae,

but have an enormous expansion in the hemispheres. The ventricular fastigium is the only structure which can be definitely recognized, and it appears on the ventral surface of the arbor vitae, lying almost at the caudal extremity, and is succeeded by only two rudimentary folial groups which represent lobulus A and lobulus B 1 of the larger lobulus B. The fissura secunda lying, as it should, in front of the arbor lobule connected with the paraflocculus is determined as the ill defined fissure lying between the second of the peculiar rays of lobulus C and the equally peculiar terminal tail-like outgrowth from the medullary substance which forms ray B 2, the chief connecting link with the lobulus paramedianus and the paraflocculus. The determination of the fissura primaria

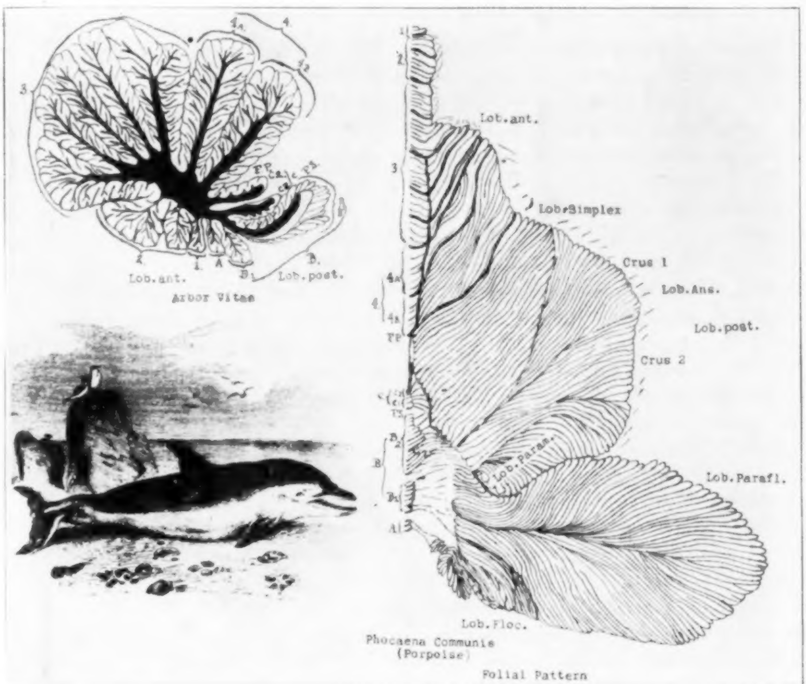

Fig. 13.—Phocaena communis (porpoise).

divides the arbor vitae into an enormous expansion comprising almost the entire surface of the arbor vitae as the anterior lobe, and a small, peculiarly arranged group of rays with only a minimum of folial representation as the posterior lobe. With this as a basis, the lobules and rays of the anterior lobe may be subdivided in a relatively satisfactory manner. The medullary substance of the arbor vitae of *Phocaena* presents a rather remarkable appearance. It consists of a relatively large mass of white matter which is almost completely disposed in the anterior lobe, with only a small caudal extension into the posterior lobe. The anterior medullary substance is roughly quadrangular and appears in an oblique plane directed from behind forward and upward. From its cephalic extremity protrudes a heavy extension forward from which arises a fan-shaped group of medullary rays. At the point where the fissura primaria (?)

approaches the ventricular fastigium the medullary substance suddenly undergoes a marked reduction and gives off the medullary rays which form lobulus C, the small ray A and the rays which form lobulus B. The medullary substance is drawn out into a curved tail-like extension which forms the core of the chief portion of lobulus B.

THE MEDULLARY RAYS

Ray 1 appears as a slender stalk proceeding directly downward, giving off a few lateral branches. The next two medullary rays arising independently from the ventral surface of the anterior medullary substance, the first being small and the second more subdivided, may apparently be grouped together as ray 2. The next group of rays comprises the major portion of the arbor vitae and presents itself as a group of five stalks arising from the enormous anterior extension of the medullary substance. The first of these is a thick, heavy stalk advancing directly forward and undergoing secondary division into two of the peculiar elongated frondlike developments which are characteristic of the arbor vitae of *Phocaena.* Following this, there are three long slender extensions from the medullary substance which appear as the leaves of a fan. These slender prolongations are richly supplied with lateral branches many of which undergo secondary subdivision. The last one is the most extensive in lateral width and presents a division at its summit into two major portions. The next two rays, ray 4 A and ray 4 B, arise from the dorsal surface of the medullary substance as two typical long drawn out frondlike groups of folia which present in their center a relatively thick medullary ray giving off numerous lateral side branches the majority of which are divided at their extremities. Ray C is divided into a U-shaped structure which arises from the posterior medullary substance, the cephalic branch from the caudodorsal angle of the medullary substance and the caudal branch from the tail-like extension of the medullary substance, and proceeds almost directly backward, presenting cortical tissue practically only on their unopposed surfaces. Lobulus B presents a structure which is somewhat reminiscent of the twisted lobulus C of the ungulate, being markedly convex with its ventral aspect practically bare of cortical tissue, while its dorsal surface presents a number of rudimentary branches forming definite folia. The peculiar arrangement of the folia as they leave this bare caudal surface is indicated by the folia which begin at once to draw away from the midline into the hemisphere. Ray B 1 appears as a small slender outgrowth at the base of ray B 2, presenting a few lateral branches. Ray A is an insignificant stem arising from the ventral surface of the posterior medullary substance.

THE LOBULES

The various lobules based on this tentative identification of the medullary rays present a peculiar and unfamiliar appearance. Lobulus 1 appears as an insignificant group of folia forming the cephalic wall of the ventricular fastigium. Lobulus 2 appears to be composed of two folial groups developed on two independently arising medullary branches. The first stalk is relatively simple, being somewhat more developed than lobulus 1. The second stem is somewhat larger, and it undergoes a definite expansion as the ray leaves the medullary substance. At its summit it is divided into two groups of lamellae. Both of the rays forming lobulus 2 arise from the ventral aspect of the medullary substance. The next group of rays may be combined together to form lobulus 3. This lobulus is complicated and is made up of four groups of folia, the first being the largest and being subdivided into two subsidiary portions. The two

succeeding sublobules form narrow frondlike folial groups, while the most caudal is distinctly caudal in form, its apex being directed toward the medullary substance and the base at the periphery. This group of sublobules forms a large triangular mass making up the major part of the anterior lobe. Lobulus 4 appears to be made up of two folial groups which are independent of each other, and are relatively richly foliated. Lobulus C is subdivided into two rudimentary arbor divisions presenting cortical tissue only on the nonopposed surfaces of the U-shaped medullary extensions. Lobulus B has a minor representation in the arbor, but expands immediately on leaving the midline into the enormous paraflocculār formation and is subdivided into lobulus B 2 and lobulus B 1. Lobulus B 2 is scimiter-shaped, the dorsal aspect being subdivided into a large number of folia, and the ventral aspect being formed chiefly by the medullary ray with a film of almost undifferentiated cortical tissue covering it. This in the folial pattern is seen to be a peduncular formation which expands into the enormous folial pattern of the paraflocculus. Lobulus B 1 is a simple, poorly differentiated lobulus. Lobulus A is a simple folial group.

THE FOLIAL PATTERN OF PHOCAENA COMMUNIS

The folial pattern of the dolphin presents a peculiar appearance owing to the fact that the paraflocculus forms fully a third of the entire substance of the hemisphere. The lateral expansion of lobulus B forms the greater part of the posterior lobe, the entire anterior lobe representing only a negligible contribution to the hemisphere. If the identification of the fissura primaria is accepted as correct, the fissure appears at almost the most caudal part of the vermal folial pattern. The entire vermal extent of the posterior lobe corresponds to about one fifth of that belonging to the anterior lobe. The fissura secunda appears as a definite line of demarcation between the lobulus paramedianus and the parafloccular formation. The folial pattern of the anterior lobe shows an absolutely definite division into vermal and lateral portions. Lobules 1 and 2, and the cephalic third of lobulus 3, do not present any lateral extension, the folia being confined entirely to the vermal midline, presenting a few medial subdivisions. Lobulus 1 presents only two small vermal folia while lobulus 2 consists of five or six folia. The middle and caudal thirds of lobulus 3 present definite lateral extensions. The caudal half of lobulus 3 presents a definite paravermian sulcus into which the folial sulci descend, and only with considerable difficulty can the proper continuation of each folium into the hemisphere be identified. The lateral extensions of the caudal folia of lobulus 3 present a few vermal folia which extend into the paravermian groove and then pass on to the periphery. The lateral extensions are not so numerous, as the vermal folia turn forward at quite an angle. Lobulus 4 consists of two groups of folia corresponding to the two medullary rays. These vermal folia are strongly limited by the paravermian groove, the folia continuing outward; those belonging to 4 A present the emergence of a number of submerged folia from the depths of the fissure separating lobulus 3 from lobulus 4. Lobulus 4 B consists of a series of slender folia continuing outward to the periphery and beginning to present the appearance of the folia forming the lateral expansions of lobulus C. Lobulus C presents an almost rudimentary folial development of two groups of only two vermal folia each. These folia, however, are supplied with a strong peduncle which diverges markedly from the base of the medullary rays and immediately expands into an enormous structure composed of a series of lamella arranged in a more or less definite form as a lobulus simplex, consisting of narrow strip-

like parallel folia that are marked off from the succeeding folia which establish the ansiform formation with its crus 1 and crus 2. Crus 1 and crus 2 appear as two groups of converging fanlike folia the mesial extremities of which form an intercrural sulcus. Then there succeeds a series of folia which gradually diminishes in extent and concludes as a group of submerged folia joining the folia of the paraflocular formation. This group of folia corresponds to the paramedian formation. Lobulus B presents two definite groups of folia. A caudal group, lobulus B 1, consists of six or seven folia; these are connected by a strong bare medullary peduncle with the enormous parafloccular formation. The remainder, lobulus B 2, presents a definite arbor structure which expands into a lateral extension connected with the caudal portion of the large lobulus representing the ansiform and paramedian formations. The major portion of lobulus B 2 is connected with the curled under folia forming the lobulus paramedianus. The parafloccular formation appears as a series of long slender folia which extend outward into an enormous structure, gradually coming to an apex and returning on itself, and thus forming a definite interparafloccular sulcus. This enormous parafloccular formation is turned underneath the projecting mass of what corresponds to the ansiform formation. It forms the ventral third of the entire cerebellar mass. Lobulus A consists of only two folia which are connected by means of a narrow peduncle with the lobulus parafloccularis which occupies an excavated corner in the mesial and caudal aspects of the lobulus parafloccularis. These folia form a series of extended rosets, diminishing progressively as the median line is approached.

Lobulus 1 and lobulus 2 show a common peduncular insertion into the medullary substance. Lobulus 3 has two peduncles, one for the cephalic third, the other for the caudal two thirds. Lobulus 4 has a separate peduncle. Lobulus C has a simple broad implantation, while the paraflocculus constituting the major portion of the posterior lobe is implanted laterally and ventrally to lobulus C.

PHYSICAL CHARACTERISTICS OF PHOCAENA COMMUNIS

The dolphin is a representative of the much altered aquatic mammals who have acquired an extensive adaptation to a new environment. The aquatic mode of life in connection with the retention of the needs connected with their type of dietary has resulted in an active, wide ranging type of animal capable of great speed and agility. The dolphin attains usually a length of from 8 to 10 feet. The body is fishlike and does not show any external differentiation between the head and the body. The eyes are small and laterally placed, and have no overlap in the visual fields. The eyes are incapable of movement and are of use only under water and at close range. The jaws can be opened to a moderate extent. The tongue is short and is not protrudable. The fore extremities are reduced to a pair of fins which are used in swimming and possess but little unilateral independence. The hind limbs have been entirely suppressed, as far as their surface representation is concerned. The tail is broad, horizontally fluked and powerful. The dolphin is capable of considerable speed, can leap for some distance out of the water and is possessed of great agility in its pursuit of food and its contacts with friends and enemies.

MONODON MONOCEROS (NARWHAL)

The identification of the various fissures and, therefore, of the lobes and lobules of the arbor vitae presents the same difficulties which were experienced with *Phocaena*. The identification of the ventricular fastigium is easy, quite

a gap appearing between the lobules of the anterior and posterior lobes. A number of fissures, however, would qualify as the fissura primaria, especially one which approaches somewhat from behind and which appears in about the same position as that determined for the fissura primaria in *Phocaena*. A combined study, however, of the arbor vitae and the folial pattern seems to indicate that this is rather the fissura secunda, and that the fissura primaria lies in front of the two rays which precede the fissura secunda. The fissura primaria, therefore, proceeds from above downward and somewhat forward, and approaches the fastigium almost at its apex. With these surface markings identified, the anterior lobe is shown to be considerably larger in extent than the posterior lobe.

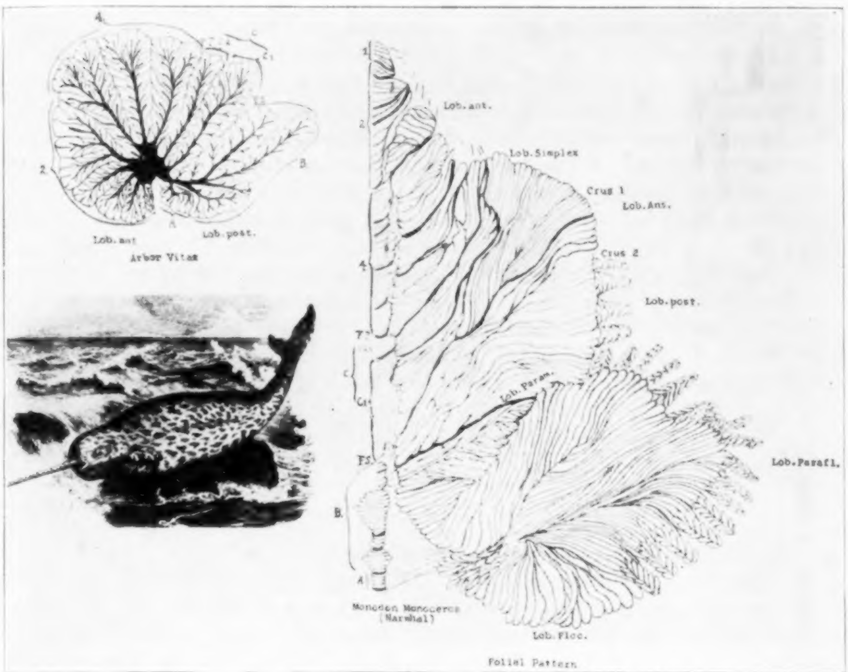

Fig. 14.—Monodon monoceros (narwhal).

The medullary substance consists of a large cephalic condensation from which arise the various rays, subdividing the lobe into its lobules. The posterior medullary substance is much smaller, and consists of a tapering protrusion of medullary substance into the posterior lobe, from which dorsally arises ray C, and from its caudal extension, rays A and B.

THE MEDULLARY RAYS

Ray 1 appears to be incorporated with the superior medullary velum as a well defined lingula. The medullary rays forming lobulus 2 arise as a group of three independent stalks the first of which is slender and gives off only lateral branches; the second is heavier and, in addition to lateral branches, presents a terminal division, while the third is still heavier and possesses the same sort

of division. These independent stalks are then followed by a heavy cephalic extension of the medullary substance which gives rise to two primary divisions; the first gives off only small lateral twigs while the other gives off extensive cephalic branches. Ray 4 takes origin by means of a thick, heavy extension upward of the medullary substance. It gives rise at its summit to three diverging stalks, all of which are richly subdivided and terminate in bushlike folial collections. The rays for lobulus C arise as two independent slender extensions of the medullary substance which gives off a great number of lateral subdivisions. Ray B arises as a direct extension backward of the medullary substance, giving rise to a thick ventral branch, which is not extensively subdivided, and a dorsal branch, which divides into three slender stalks, the middle one being the most extensive. Ray A is an angulated, slender ray which arises from the root of ray B.

THE LOBULES

Lobulus 1 consists of a lingula presenting three or four folia. Lobulus 2 consists of three sublobules provided with independent medullary rays, and a consolidated lobulus consisting of about five sublobules, formed by the bifurcation and further division of the most dorsal of the rays entering into the formation of lobulus 2. Lobulus 4 consists of three chief sublobules, each of which is subdivided. All these lobules are somewhat pyriform, the base being at the periphery, and they decrease in size from before backward. They consist of elongated folial groups which, at the periphery, fan out into rather extensive lamellar clusters. They are quite deep. Lobulus C consists of two groups of folia produced by the formation of two medullary rays, and are similar to the sublobules of lobulus 4 but are less extensive. Lobulus B consists of four chief subdivisions, the dorsal two of which are long slender prolongations from the upper medullary ray, succeeeded by a short, ill defined sublobulus, and then by a larger terminal ventral lobulus. Lobulus A consists of a group of simple folia, partially overhung by the caudal termination of lobulus B.

THE FOLIAL PATTERN OF MONODON MONOCEROS

The narwhal presents a degree of complexity unequaled by any folial pattern which has been examined. The lateral hemisphere of the elephant exceeds it in bulk, but is much more easily divisible into the main components of the hemisphere than are the folia of the narwhal. The chief difficulty in the division of the hemisphere into its constituent lobules is the fact that there is apparently no definite relationship between the hemispheral lobules and the lobules of the arbor vitae, the major subdivisions of the folial grouping apparently falling midway between the divisions of the arbor vitae, so that each one of the folial extensions belongs half to the preceding and half to the succeeding arboreal division. A similar difficulty arises in the division of the lobules at the periphery, since here also there is no clear differentiation between the folial groups, each succeeding group being connected with the preceding folial group, usually in the depths of the fissure separating them, by a large mass of connecting and communistic folia.

The fissura primaria, identified as well as possible, begins at about the middle of the arbor, but proceeds sharply forward so that it divides the folial pattern into an almost inconsequential anterior lobe and an enormous posterior lobe. The fissura primaria passes outward and then forward in a rather irregular, sinuous line to the periphery. The fissura secunda appears between what may be identified as lobuli B and C. It cannot be identified with any

degree of assurance in the hemisphere on account of the fact that it is difficult to determine where the lobulus paraflocculari begins. A well defined fissure exists between the main mass of what may be considered the lobulus ansiformis and the enormous extension of the paraflocular formation. The group of folia, however, interposed between this fissure and the main mass of the paraflocculus, presents such a striking resemblance to the paramedian formation that it is difficult to decide whether the fissura secunda lies in front of, or caudal to, this structure.

The anterior lobe shows a definite division into a vermal and a lateral portion, there being a deep, narrow paravermian groove separating the vermal and the lateral folia. Into this groove the sulci separating the vermal folia pass, and then run forward for a considerable distance before passing outward into the lateral extensions. The exact correspondence of the lateral extension with the proper group of vermal folia is extremely difficult to determine. Lobulus 1 appears as a lingula, and presents four or five well defined folia which caudally become somewhat more elongated, but without forming any definite lateral extension. This group of folia forming lobulus 2 consists of four well defined groups. The first group consists of two or three small folia similar to those of lobulus 1. The second cluster of folia are drawn outward to an apex. The third portion consists of a single partially subdivided folium which is applied to the lateral aspect of the preceding group. The fourth portion consists of an initial folium which extends outward to participate in the apex formed by the two preceding groups of folia; the remaining lamellae are rapidly reduced to vermal folia of meager dimensions, the caudal of which are connected in the depths of the paravermian fissure with a peculiar extension into the lateral hemisphere, and the distal folia of which are placed at right angles to the usual direction of the hemispheral folia. Lobulus 4 consists of four well defined groups of vermal folia bounded by the deep paravermian fissure through which the folial sulci proceed to become continuous with those separating the folia of the hemisphere. The folial extension of lobulus 4 consists of an extremely irregular series of folial groupings not presenting any definite characteristics but rather an extreme degree of variability and variety in the conformation, direction and arrangement of the folia. The folia, however, become progressively longer, as the chain is followed caudally, showing a constant tendency to diminish in number as the periphery is approached, so that the lateral extent of this group of folia is considerably less than its mesial representation. Lobulus C consists of two separate, distinct groups, a cephalic vermal lobulus C 2 consisting of two simple folia connected with an irregular lobulus that does not reach the periphery. This lobulus, from its location and vermal connections, should represent the lobulus simplex. The vermal folia of lobulus C 1 appear as two groups of folia which converge in the paramedian sulcus, becoming more and more oblique and less and less extensive. Connected with these two groups of vermal folia there is found an extremely irregular arrangement of hemispheral folia forming an irregular pattern of succeeding folial groups presenting the suggestion of an ansiform formation, a poorly developed crus 1 and crus 2, with the production of an intercrural sulcus. The folia of crus 2 and the paramedian formation present a series of rosets at the periphery which afford the implantation into the medullary substance. Lobulus B presents four definite subdivisions in the folial collection: (1) a submerged group of six folia, (2) a group of twelve or fourteen folia which represent the long extension backward of the middle ray of lobulus B, (3) a few submerged folia representing the small folium between the dorsal and ventral branches of lobulus B and (4) a simple folial

group, the ventral branch of lobulus B. These folial groups are continued outward by means of a heavy, dense peduncle with the caudal half of the ansiform formation or a large paramedian formation. The paraflocculus consists of an S-shaped curve of folial strips, beginning with a structure which presents a large but subordinate roset formation with two definite crura and a series of rosets in its second portion. After this a long series of folia appears which extend outward and at their lateral extremities present the peculiar implantation found in *Phoca*, a series of elongated folial rosets formed on a peduncle which is inserted into the medullary substance and at its summit gives origin to at least two of the parafloccular folia. These are arranged as a fringe around the entire extremity of the paraflocculus. The rest of the folia of the paraflocculus are arranged in a series of elongated folia which converge at various points on each other, forming at least two interparafloccular sulci. The caudomesial angle of the parafloccular formation is excavated to receive the lobulus floccularis, consisting of a series of converging, rather broad folia, terminating in an elongated double roset. The base of the flocculus is somewhat covered by the base of the parafloccular formation itself, and is apparently continuous with a peduncle that develops at the base of the folial roset which forms lobulus A.

The implantation of the various lobules into the medullary substance is relatively simple. Lobulus 1 and the major portion of lobulus 2 are implanted together. The lobulus simplex and the lobulus ansiformis share a rather wide peduncle. The lobulus paramedianus presents the peculiar roset-like peduncles which develop as a fringe along this part of the cerebellum. The paraflocculus also possesses the same sort of an implantation, the rosets being closely packed and succeeding one another without any appreciable interval.

PHYSICAL CHARACTERISTICS OF MONODON MONOCEROS

Cetacea represent a group of mammals derived from a stock which also gave rise to *Carnivora*. *Cetacea* are carnivorous and their specialization has resulted from an early adoption of an aquatic habitat and a carnivorous dietary which made *Cetacea* a roving type of aquatic mammal. Like *Sirenia*, its aquatic habitat has rendered *Cetacea* essentially fishlike in form. The narwhal presents an elongated, tapering outline, the head and body being externally continuous and not presenting any cervical differentiation. It is usually from 12 to 15 feet long. The eyes are small and situated laterally. The visual fields do not overlap, and the eyes are immobile. The tongue is small. Protruding from the upper jaw is a twisted spear, which is usually single, although it may be double. The forelimbs are transformed into flippers which externally do not show any joints; the hind limbs do not show any external development. A dorsal fin is not present. The tail is formed of thickened integument and is provided with two heavy flukes situated in a horizontal plane. The narwhal proceeds through the water by swimming movements of the body and tail. It is capable of great speed and can maneuver with the greatest facility, grace and agility.

FELIS DOMESTICA (CAT)

The arbor vitae of the cat in median section presents a somewhat oval outline. The fissura primaria is almost vertical in position, situated a little in front of the midpoint of the cerebellum and almost directly opposite the approach of the ventricular fastigium to the medullary substance. The ventricular fastigium is almost perpendicular. The fissura secunda appears in the

usual position, separating lobuli C and B. There is some disparity in the division into anterior and posterior lobes, the posterior lobe occupying a little more than half of the mesial surface. The medullary substance is relatively concentrated as a protuberant mass in the anterior lobe, the posterior lobe receiving a caudal extension of the medullary substance of the anterior lobe directed mainly upward into lobulus C.

THE MEDULLARY RAYS

Ray 1 is a single branch arising from the ventral surface of the medullary substance of the anterior lobe, presenting a few lateral offshoots. Ray 2 consists of a rather massive extension forward of the main mass of the medullary substance and gives rise to three independent medullary branches which show

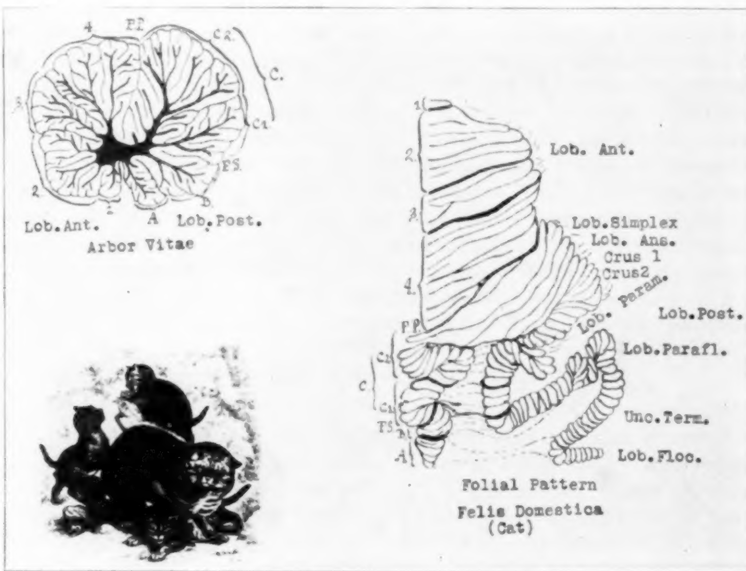

Fig. 15.—Felis domestica (cat).

a slight consecutive increase in complexity. Ray 3 arises at the junction of the root of ray 4 with the main mass of the medullary substance and may be recognized as an independent branch. It is a simple, slender ray, giving off side branches, and ends in a secondary subdivision. Ray 4 is a somewhat heavier stem arising almost perpendicularly from the dorsal surface of the medullary substance and dividing into two main branches which again undergo a single division. Ray C, subdivided into ray C 2 and ray C 1, represents the chief caudal extension of the medullary substance of the posterior lobe, being directed upward and backward as a relatively thick stem, ray C 2 giving off simple branches from its cephalic and caudal aspects, and then undergoing an extensive terminal division. The cephalic group of terminal branches supports transverse folia, while the caudal branches participate in the formation of a loop in the vermis. In the depths of the fissure between rays C 1 and C 2 are found two branches which, when followed into the folial pattern, form the basis for the twisting turn

of the vermal folia. Ray C 1 arises as a single independent shoot close to the junction of C 2 with the main mass of the medullary substance of the posterior lobe. It undergoes a rather simple type of division, and its upper part participates materially in the curving loop of the vermal pattern. Ray B arises as a single slender stem below the origin of ray C, undergoes simple division and presents only a few lateral branches. Ray A consists of a single stem which presents a few simple side twigs and ends in a bifurcated termination.

THE LOBULES

The lobules produced by the division of the medullary substance into the medullary rays is made up of a simple lobulus 1, consisting of a single surface folium; a more complicated lobulus 2, which has three medullary rays as its basis, and presents an increasing series of surface folia; a lobulus 3, apparently from its origin, an independent lobulus comprised of a few simple folia, and lobulus 4, which presents three chief subdivisions. It forms the cephalic limit of the fissura primaria and is simple in its composition. Lobulus C is subdivided into lobuli C 2 and C 1. Lobulus C 2 presents a number of cephalic folia in the depths of the fissura primaria and a group of surface folia, the most cephalic of which have the usual transverse arrangement, while the caudal group represents the beginning of a rather simple vermal twist in the region of lobuli C 1 and C 2. Between lobulus C 1 and lobulus C 2 there are a number of submerged folia which are interested in the formation of the twisting vermal turn. Lobulus C 1 is relatively simple in the arbor pattern, but presents a considerable degree of convolution in the folial pattern. Lobulus B is a simple lobulus consisting of three or four folia. Lobulus A is an uncomplicated lobulus presenting only two or three surface folia.

THE FOLIAL PATTERN OF FELIS DOMESTICA

The cat presents a rather simple folial pattern. The anterior lobe is relatively extensive in the folial pattern, occupying at least half of the surface of the cerebellum. The fissura primaria, which limits the anterior lobe caudally, is relatively simple and extends outward on the hemispheral surface, gradually inclining forward to the periphery. The fissura secunda appears in rather an oblique position separating lobuli C and B. Its continuation outward seems to mark off the paramedian from the parafloccular formation. Lobulus 1 apparently is confined entirely to the vermis and consists of a single surface folium. Lobulus 2 presents a number of vermal subdivisions which become lost as the folia are followed outward into the hemisphere. The folia show a definite tendency to condensation toward the periphery. Lobulus 1 and lobulus 2 are inserted by means of a common medullary stem into the underlying white substance. Lobulus 3 is a simple lobulus consisting of three folia, which are reduced to two and inserted by an independent peduncle. Lobulus 4 consists of a group of parallel folia, there being but little reduplication in the vermis region and only a slight reduction in the number of folia constituting the lateral portion of the lobulus. Lobulus C can be divided into two divisions. A cephalic group of two folia, which are continued outward as simple folia arranged in a parallel fashion, corresponds to the lobulus simplex. The rest of the vermis forms an S-shaped turn, the first limb of the S being to the left, crossing to the right and then again to the left, the apex of the curve being in all cases on one side or the other of the midline. The lateral portion of lobulus C presents a fairly complicated arrangement with a definite lobulus ansiformis and the

development of crus 1 and crus 2, and the formation of a sulcus intercruralis. Crus 1 continues with rapidly shortening folia, the apex of the ansiform arrangement being produced by a roset, following which appears crus 2 which rapidly returns along the course of the folia of crus 1. At its transition into the lobulus paramedianus, a definite folial roset appears. The lobulus paramedianus is connected with the caudal vermal portion of lobulus C 2 and with lobulus C 1 and presents a regular series of folia which continues backward to the position of the fissura secunda where the folial chain turns on itself and continues out into the lobulus paraflocculàris. The folial chain, following the S-shaped loop forming the major portion of lobulus C, returns to the midline and presents a few simple successive folia corresponding to lobulus B. Lobulus B is based on a peduncle which is continued outward in the general direction of the lobulus parafloccularis. The lobulus parafloccularis arises as a chain of lamellae directly continuous with the lobulus paramedianus and continues forward. As it curves around the lobulus ansiformis it develops a double group of rosets. The lamellar chain then continues backward paralleling its previous course outward and ends in a long chain of folia, the uncus terminalis. The lobulus parafloccularis occupies the usual position seen in the carnivore type of cerebellum, being situated ventral and lateral to the general group forming the lobulus simplex, lobulus ansiformis and lobulus paramedianus. Lobulus A consists of a simple group of rapidly diminishing vermal folia. It is continued outward in an ill defined peduncle in the general direction of the lobulus flocculàris. The lobulus floccularis appears as a simple group of folia directly following the uncus terminalis. The lateral extensions of lobulus C are inserted by a large peduncle into the medullary substance, while the parafloccular formation is inserted by an extended application of the folia to the medullary substance. The lobulus floccularis lies in the usual position between the peduncle of the cerebellum and the parafloccular formation.

Lobuli 1 and 2 have a common peduncular implantation into the medullary substance. Lobulus 3 and lobulus 4 share a broad attachment. Lobulus C has one broad medullary implantation, with the paraflocculus lateral and ventral to lobulus C.

PHYSICAL CHARACTERISTICS OF FELIS DOMESTICA

The cat family all present similar characteristics and vary chiefly in size, ranging from the full grown lion or tiger to the small cat. The head is rounded, with a short jaw, and the eyes are placed well forward so that the visual fields are overlapping. The eyes are conjugated in their movements. The ears are of medium size, rounded and fairly movable. The tongue is large but not prehensile. The neck is short and presents a considerable range of movement. The limbs are short and exceedingly powerful in the largest member of the family. The body is heavy and rather elongated. The tail is long and is apparently of some equilibratory use in the animal's flying leaps. The members of the family in general are possessed of an extreme degree of grace, agility and perfection of timing and rhythm. They are extremely agile and active to a degree. They cannot maintain a rapid pace in running for any great distance, but their movements of attack and defense are of unbelievable rapidity and precision. The four limbs are used in locomotion, but all are capable of a certain degree of unilateral independence which is, of course, much greater in the fore limbs.

CANIS LATRANS (COYOTE)

The arbor vitae of the coyote presents a more or less quadrilateral form. The fissura primaria appears somewhat behind the middle and is directed downward

and forward toward the ventricular fastigium which is placed rather cephalad to the middle of the lower part of the arbor pattern and is relatively wide open. The line of the fastigium and fissura is more or less oblique from behind, forward and downward. The fissura secunda appears between lobuli B and C and is somewhat below the level of the medullary substance. The arrangement of the fissura primaria and the fastigium divides the median section of the cerebellar vermis into more or less equal halves, the fissura primaria, however, as already indicated, being rather oblique from behind, forward and downward, owing to the overgrowth of lobulus 4. The medullary substance appears consolidated in the anterior lobe, being a large, heavy mass with a caudal termination markedly constricted by the fissura primaria and the ventricular fastigium, and it is drawn out into the posterior lobe, supplying the framework of that lobe.

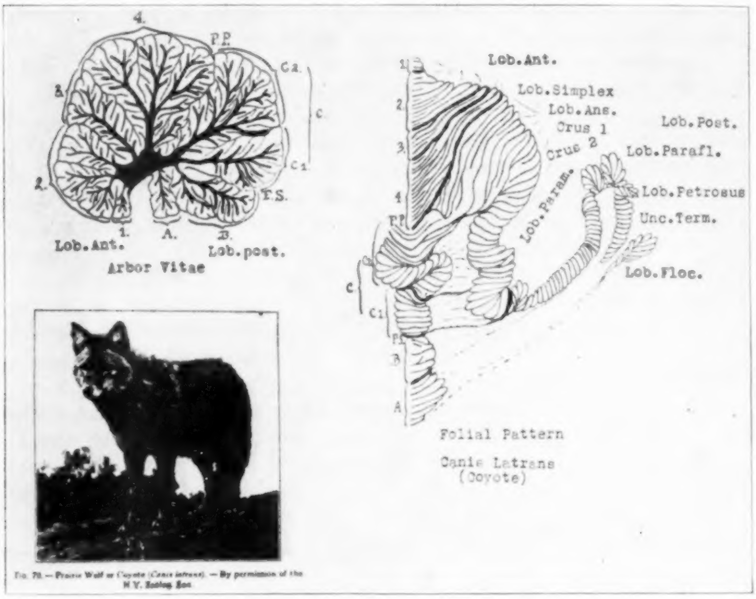

Fig. 16.—Canis latrans (coyote).

THE MEDULLARY RAYS

Ray 1 is a narrow stalk, arising close to the ventricular fastigium, and giving off simple side branches. Ray 2 consists of the extension forward of the anterior medullary substance, and gives rise to two branches, each forming a subdivision of lobulus 2. The first of these immediately divides into two stems which diverge and give off rather numerous twigs, while the dorsal branch does not divide until near its termination and gives off relatively few side shoots. Ray 3 arises as an apparently independent ray from the substance of the medullary center between the origin of the groups of rays forming ray 2 and ray 4. It arises as a large stalk directed forward, giving off simple side branches, and ends in a terminal bifurcation. Ray 4 consists of a heavy prolongation upward of the medullary substance. It arises almost vertically above the fastigium, giving off a number of simple branches, and then divides into three subdivisions, each of which is

extensively subdivided. In the depths of the fissura primaria, ray 4 gives off one major caudal stem. The posterior medullary substance consists of a continuation backward of the anterior medullary substance as a somewhat attenuated mass, which almost immediately divides into three terminal branches forming rays C 2, C 1 and B. Ray C 2, the stoutest of the three, is the chief continuation caudally of the medullary substance of the lobe and gives off a number of subsidiary branches which are hidden in the depths of the fissura primaria. It subdivides into four chief rays which form a terminal spray producing the surface configuration of lobulus C 2. The last ray, which does not quite reach the surface, does not present any lateral derivatives and is apparently concerned in the sigmoid twist of the vermis, forming the stem for the mass of folia producing one of the curves in the vermal pattern. Ray C 1 arises just below the origin of ray C 2, gives off lateral branches and then divides into a series of branches which appear as serial lamellae in the folial pattern. Ray B arises still further caudally below the origin of rays C 1 and C 2. It almost immediately divides into two branches, a large dorsal and a smaller ventral stalk, the former giving rise to a considerably greater number of twigs. Ray A is a simple stalk arising close to the caudal boundary of the ventricular fastigium.

THE LOBULES

Lobulus 1 is small with only two or three minor folia. Lobulus 2 is considerably larger and consists of three distinct portions which, however, do not show any particular distinguishing characteristics. Lobulus 3 is a simple lobulus with five surface folia. Lobulus 4 is extensive on the vermal surface, and presents three definite subdivisions as a result of this division of ray 4. Lobulus C is divided, as are the rays, into lobulus C 2 and lobulus C 1. Lobulus C 2 is rather more extensive and consists of three portions corresponding with the branches of the medullary ray. The varying characteristics of these are seen in the folial pattern, the first corresponding to the lobulus simplex and the second to the twisting vermal pattern. The under surface of ray C 2 gives rise to three or four folia which are continued outward to form the stem of the twist in the vermis. Lobulus C 1 is a conical shaped lobulus which caudally presents an extensive group of folia. Lobulus B presents two definite subdivisions but consists only of serial folia. Lobulus A is relatively insignificant and is formed by a simple group of folia on a single stem.

THE FOLIAL PATTERN OF CANIS LATRANS

The pattern of the coyote is an arrangement of folia and lobules typical of carnivorous animals. The fissura primaria separating the anterior and posterior lobes arises from about the midpoint of the vermis and proceeds outward in a relatively simple form, directed considerably forward, so that the lateral extent of the lobe is much less than its extent at the midline. The fissura secunda appears in its usual position between lobuli B and C and is continued outward into the folial pattern to the junction of the lobulus paramedianus and the lobulus parafloccularis. The anterior lobe is fairly simple and consists of a series of folia presenting a gradually increasing width. The folial arrangement of the posterior lobe is characteristic of the typical pattern for carnivorous animals, presenting a fairly diagrammatic disposition of all of the various components of the lobulus complicatus.

Lobulus 1 consists of three simple vermal folia. The folia of lobulus 2 present a considerable vermal differentiation and lateral extensions which successively

increase the caudalmost folium showing the greatest lateral disposition. There are a number of short vermal sulci. Lobulus 3 is simple and narrow, consisting of only one complete folium which is subdivided mesially into at least five subsidiary folia. Lobulus 4 presents a similar arrangement, the peripheral portion consisting of only two folia which are increased to ten or a dozen at the midline by the appearance of short vermal sulci.

The posterior lobe is characteristic. The cephalic portion of lobulus C 2 is relatively simple in its vermal division. It consists of a number of folia which run from the midline to the periphery without any material irregularity in their disposition. As they are continued outward into the lateral hemisphere, they are displaced somewhat backward by a group of folia which emerge from the depths of the fissura primaria, corresponding to the submerged group of folia in the fissure arising from the cephalic aspect of ray C 2. These folia represent the lobulus simplex. The caudal portion of the vermis of lobulus C 2 shows a characteristic S-shaped twist which begins on the right side of the vermis, crosses to the left and returns to the right and then to the midline. The portion of the twisted vermal lamellar chain is connected laterally with the lobulus ansiformis and the lobulus paramedianus.

Succeeding the simply arranged lobulus simplex, a group of folia appears which passes outward into crus 1 of the lobulus ansiformis. These folia decrease in extent until the apex of the lobulus ansiformis is reached, where the lamellar chain turns on itself and returns toward the midline, forming crus 2, and a distinct intercrural sulcus. Arriving in the paramedian position, crus 2 turns backward, straightening out into a well defined lobulus paramedianus, and continues caudally with only a slight interruption in the middle, representing an abortive attempt at a roset formation, to become continuous with the lobulus parafloccularis. Lobulus C is a simple, straight collection of vermal folia, the caudal continuation of the S-shaped curve of lobulus C 2. This simple folial chain is connected across the paramedian fissure with the terminal folia of the lobulus paramedianus as it merges with the lobulus parafloccularis. Lobulus B presents a simple series of five or six vermal folia. It is apparently connected by a peduncle with the paraflocculur formation. The paraflocculus begins at the termination of the lobus paramedianus, and is separated from it by the fissura secunda. It immediately develops a folial roset; then there follows a long, straight chain of folia which continues around crus 2 and crus 1 almost to the anterior lobe. It here turns on itself forming a double series of rosets and then a distinct protrusion outward as a roset forming a distinct lobulus petrosus. This is completed by the uncus terminalis. Lobulus A presents a vermal roset the peduncle of which is continued outward toward the lobulus flocculari which consists of a short folial chain and roset situated in its usual position between the cerebellar peduncle and the lobulus parafloccularis.

The various lobuli of the anterior and posterior lobes show a relatively simple arrangement of their implantation into the medullary substance. Lobuli 1 and 2 are implanted together; lobulus 3 and lobulus 4 are implanted together, and the lobuli simplex, ansiformis and paramedianus have a broad support on the medullary substance, lateral and ventral to which is inserted the entire length of the lobulus parafloccularis and the uncus terminalis.

PHYSICAL CHARACTERISTICS OF CANIS LATRANS

The coyote has the typical body form of the domestic dog, well developed and carried on four relatively short legs. The neck is short but quite mobile. The eyes occupy an anterior position, possess overlapping fields of vision and are well

conjugated in their movements. The tail is bushy and has no particular characteristics beyond that of utility. The animal is swift, possessing a considerable degree of speed without, however, the extreme agility and acrobatic powers of the cat family. There is some unilateral independence in the movements of the legs, but they are used chiefly for locomotion and for digging in the ground. The coyote's need for equilibrium is moderate.

CANIS VULPES (FOX)

The arbor vitae of the fox is roughly quadrilateral in form, being somewhat greater in its vertical than its horizontal diameter. The fissura primaria is almost vertical and is situated directly above the fastigium which is vertical and fairly wide. The fissura secunda appears in its usual position and is almost in direct

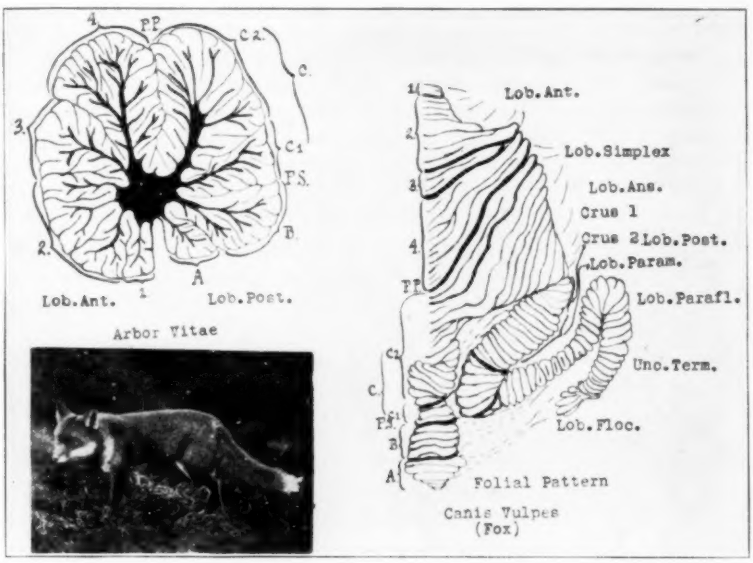

Fig. 17.—Canis vulpes (fox).

continuation backward of the axis of the medullary substance. The arbor vitae is divided into approximately equal anterior and posterior lobes by the approach of the fissura primaria to the ventricular fastigium. The medullary substance is collected chiefly in the center of the anterior lobe as a large mass of white matter, being continued backward as an attenuating structure which is continued upward into ray C 2.

THE MEDULLARY RAYS

The medullary rays are relatively slight except ray 4 and ray C 2, and the arbor vitae is similar to that structure as it appears in *Felidae*. Ray 1 arises as a slender branch from the ventral surface of the medullary substance and gives off two simple series of side branches. The medullary rays forming lobulus 2 arise as three independent branches from a rather thick extension forward of the medullary substance, and divide the lobule into three parts. They are all slender and give off relatively few secondary branches, the first two

undergoing secondary division. Ray 3 does not have an entirely independent origin, but arises from the base of ray 4. It is a slender, arched ray, giving off a number of side branches. The independence of this ray can be questioned, and it may be more correct to call it ray 4 A as it indubitably belongs to the ray 4 complex. Ray 4 is considerably heavier, is almost vertical and arises from about the center of the medullary substance of the anterior lobe by means of a rather heavy extension upward of the medullary substance. It gives off cephalic and caudal branches and subdivides into two chief stalks which give off lateral shoots as they proceed to their terminal branches. Ray C arises as a single prolongation backward of the medullary substance which almost immediately divides into two branches, rays C 2 and C 1. Ray C 2 is continued upward and backward in an arched fashion, giving off cephalic and caudal branches and then breaking up into a number of simple terminal twigs, some of which undergo further slight division. One of the caudal branches presents a rather extensive division. Ray C 1 is a relatively slender ray, giving off side branches and terminating in three small twigs. Ray B arises from the caudal portion of the medullary substance of the posterior lobe, and subdivides into two chief branches, the dorsal division being much the longer and giving rise to a fair number of twigs. Ray A is a simple stalk arising close to the caudal boundary of the fastigium, presenting a few lateral branches.

THE LOBULES

The lobules produced by the division of the medullary substance are rather extensive and present a considerable degree of complexity. Lobulus 1 is relatively simple and presents a partial vermal subdivision. Lobulus 2 is considerably more highly organized and is composed of three separate sublobules, each one of which is still further subdivided, the first two being more richly foliated than the third, or most dorsal, which is quite narrow. Lobulus 3 could, with perfect propriety, be considered as only a sublobulus of lobulus 4 and termed lobulus 4 A. It is a triangular lobulus with its base at the periphery, where it is composed of a few surface folia. Lobulus 4 is relatively simple in its organization, and is composed of a number of surface folia which are divided into two groups by the terminal division of the ray and do not present definite individualities. Lobulus C 2 presents a large number of submerged folia in the fissura primaria and a moderate number of surface folia, the cephalic of which are serially arranged, while the caudal portion begins to show the complications of the twist in the vermis in this region through the peculiar arrangement of the richly divided caudal ray and the rather large submerged ray. Lobulus C 1 consists of a small number of surface folia which are serially arranged. Lobulus B consists of two groups of folia, owing to the division of ray B, the dorsal group being extensive. Lobulus A consists of a group of serially arranged surface folia.

THE FOLIAL PATTERN OF CANIS VULPES

The folial pattern of the fox shows the usual division into the anterior and posterior lobes by means of the fissura primaria which arises at about the middle of the pattern and proceeds forward and outward in a slightly sinuous course. The fissura secunda separates lobulus C from lobulus B, and is directly continuous with a division in the lateral lamellar chain which corresponds to the transition from the lobulus paramedianus into the lobulus parafloccularis. Lobulus 1 is a simple, single folium which is divided in its lateral portion. This folium, however, seems to be confined to the vermis and does not present any

definite contribution to the hemisphere. Lobulus 2 consists of (1) four short vermal folia, (2) two surface folia of considerably greater length which contribute to the hemisphere and (3) the most extended portion of the group, which is subdivided mesially but reduced to one folium at the periphery. Lobulus 3 consists of three folia, none of which reaches the periphery of the hemisphere, being shut off from it by the approximation of lobuli 2 and 4. It shows definite vermal and lateral portions. Lobulus 4 is extensive in the vermis, showing a number of sulci which continue for only a short distance. The folia continually decrease in number, only two folia finally reaching the periphery. The lateral extent of the anterior lobe, therefore, is much less than its median representation. Lobulus C presents a subdivision, as is shown in the arbor vitae, into two portions, a cephalic portion, which corresponds to ray C 2, and a caudal portion, which corresponds to ray C 1. Lobulus C 2 is again subdivided into a simple cephalic portion and a convoluted caudal portion. The cephalic folia proceed outward in a simple fashion into the hemisphere, forming a definite lobulus simplex. Succeeding the lobulus simplex is a group of progressively diminishing folia which form crus 1 of the lobulus ansiformis. Reaching the apex of the ansiform formation, the lamellar chain turns caudally and mesially forming a well defined crus 2, which, by its approximation to crus 1, forms an intercrural sulcus. The folial chain of crus 2 then turns backward into a simple paramedian formation in close proximity to the caudal and vermal portion of lobulus C 2 and lobulus C 1, with which it is connected. Lobulus C 1 consists of three small folia which are continuous with the most caudal folia of the paramedian formation. Lobulus B consists of four or five fairly wide folia which converge on a peduncle that continues outward and approaches the base of the paramedian formation. The lobulus paraflocculatis arises as a direct continuation of the folial chain of the paramedian formation. It appears as a simple chain of lamellae, which turns on itself in the region of the apex of the lobulus ansiformis, and is continued backward into an uncus terminalis. Lobulus A consists of five or six serial vermal folia set on a single peduncle which is continued outward in the general direction of the lobulus flocculatis, which succeeds the uncus terminalis and is situated between the peduncle of the cerebellum and the parafloccular formation, being made up of a single folial roset.

The implantation of the various lobules in the medullary substance is relatively simple. Lobuli 1, 2 and 3 have a single peduncle. Lobulus 4 is more or less separate, while lobulus simplex, lobulus ansiformis and lobulus paramedianus are directly implanted by a broad base on the medullary substance, lateral and ventral to which is the broad attachment of the lobulus paraflocculatis and the uncus terminalis.

PHYSICAL CHARACTERISTICS OF CANIS VULPES

The fox is small and not so heavily built as most of the dog family. It presents a somewhat elongated body, set on four slender legs; it has a moderately developed, mobile neck, a small head, eyes set well forward and quite movable triangular ears. The legs are about medium length, while the tail is long and bushy. The fox possesses a considerable degree of speed and agility. The eye movements are well conjugated and the visual fields are overlapping. The fox is capable of climbing trees with ease and celerity. The prey of the fox consists largely of mice and birds, so that it is evident that he is able to move with extreme speed and accuracy, and that the fore limbs are capable of a considerable degree of unilateral independence in their ability to catch and hold these small and relatively quick-moving victims.

CERCOLEPTES CAUDIVOLVULUS (KINKAJOU)

The arbor vitae of the kinkajou presents an oval form. It is subdivided into about equal anterior and posterior lobes by an almost vertical fissura primaria and a wide open ventricular fastigium. The fissura secunda appears in the usual position as a direct backward continuation of the axis of the medullary substance, its disposition being backward and somewhat upward. The fissura primaria and the ventricular fastigium divide the arbor vitae into approximately equal posterior and anterior lobes. The appearance of the arbor vitae is relatively light and delicate, the foliation not being extensive. The medullary substance presents a marked condensation in the anterior lobe, a distinct constriction at the isthmus between the anterior and posterior lobes and a short caudal prolongation which is chiefly concerned in the origin of ray C.

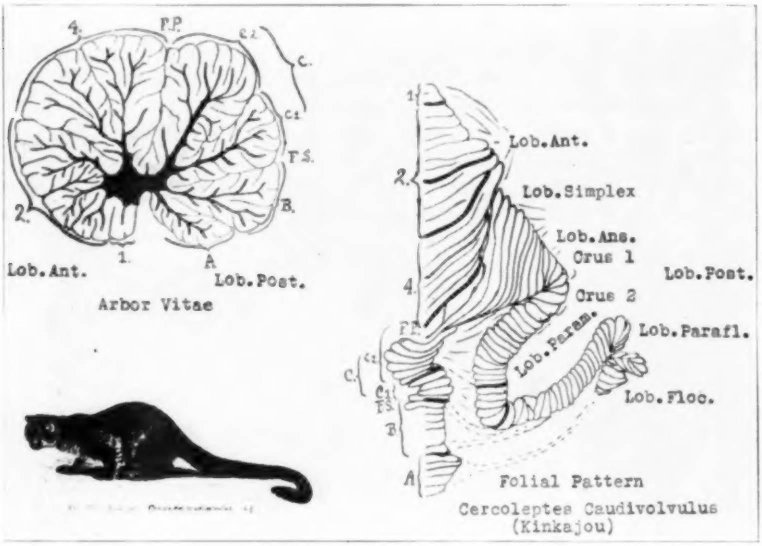

Fig. 18.—Cercoleptes caudivolvulus (kinkajou).

THE MEDULLARY RAYS

The division of the medullary substance into medullary rays is fairly simple, there being no great degree of secondary subdivision. Ray 1 appears as an unbranched stem from the ventral surface of the medullary substance. The entire medullary substance is drawn forward into the base of lobulus 2. Three rays appear to form lobulus 2, the first two being relatively simple and presenting only a few branches. The third stem might easily form an independent ray 3 if its origin occurred only a little more caudally. This ray is somewhat heavier, divides into two branches and is provided with a number of lateral twigs. Ray 4 arises vertically, as a somewhat heavier stalk, from the medullary substance, and divides into two branches, one of which proceeds cephalically and the other upward. Both of these subdivide and give off lateral branches. Ray C 2 and ray C 1 arise together as a prolongation upward and backward from the medullary substance of the posterior lobe, with a heavy base giving origin to the two branches which diverge from one another. Ray C 2 gives off one stalk in the

depths of the fissura primaria, and another, which, reaching the periphery of the arbor vitae, subdivides into a spray of terminal branches characteristic of the twisted form of the vermis. A number of small branches arise from its caudal surface. Ray C 1 arises as a straight stalk with lateral branches and divides into a terminal division of three stems. Ray B arises as a direct continuation caudally of the medullary substance of the posterior lobe. It gives off lateral branches and then divides terminally. Ray A arises from the under surface of the medullary substance close to the ventricular fastigium and gives off a series of lateral branches.

THE LOBULES

Lobulus 1 consists of a single folium forming the cephalic margin of the fastigium. Lobulus 2 presents three subdivisions; the first two are simple, while the third is larger and heavier and consists of two definite divisions. This portion of lobulus 2 corresponds to the structure called lobulus 3 in other arbor patterns when the base of the ray arises slightly more caudally. Lobulus 4 consists of two portions which do not present any particular peculiarities, except that each one is further divided into two folial groups. Lobulus C is divided into two parts. Lobulus C 2 is well defined and presents a few regular cephalic folia in the fissura primarius and a number of irregular caudal folia which participate in the vermal twist as is evident from the appearance of the surface folia that form the summit of the lobulus. Lobulus C 1 is simple and is made up of a few regular submerged and surface folia. Lobulus B consists of a series of surface folia divided into two groups. Lobulus A is a fairly well developed elongated lobulus forming the caudal boundary of the fastigium.

THE FOLIA PATTERN OF CERCOLEPTES CAUDIVOLVULUS

The pattern is comparatively uncomplicated. The fissura primaria appears somewhat caudal to the middle of the vermal disposition of the folia. It proceeds laterally and then turns rather abruptly forward. The fissura secunda appears in its usual position between lobuli B and C and is continuous with a sulcus which separates the paramedian formation from the lobulus parafloccularis. Lobulus 1 consists of a single vermal folium with a short medial sulcus. Lobulus 2 consists of a series of folia divided into two folial groups, increasing in their lateral extent, showing in the caudal folia definite vermal and lateral portions. The caudal division is compressed by lobulus 4, only one of the folia reaching the periphery. Lobulus 4 consists of a series of simple folia, only one of which appears definitely at the periphery, the rest disappearing in the fissura primaria. Lobulus C consists of two definite portions. The cephalic subdivision shows a further differentiation into (1) a portion the folia of which appear in the vermal region and continue outward into the lateral part of the lobule, a number of them converging on the fissura primaria; and (2) a caudal portion in which the vermal and lateral portions of the folia are not directly continuous but are divided by a definite paramedian sulcus. One of the folia of the cephalic portion can be traced from the vermis to the periphery—apparently the lobulus simplex. The rest of the vermis of lobulus C, comprising the caudal portion of lobulus C 2 and lobulus C 1, presents a simple curve originating on the left hand side of the vermis and extending over to the right of the midline for a short distance. These folia are continuous with the folia of the lobulus ansiformis and the first portion of the lobulus paramedianus. The folia which directly succeed the single folium of the lobulus simplex form a diminishing group comprising crus 1. This terminates at the apex of the lobulus ansiformis as a roset, crus 2 then continuing mesially in

contact with crus 1 and forming a fairly definite intercrural sulcus. The transition from crus 2 to the lobulus paramedianus is gradual as the folial chain approaches the vermis. It then turns backward and forms a series of folia connected with the vermal portion of C 1, the lobulus paramedianus. Lobulus B consists of a group of vermal folia. They surmount a definite peduncle which is continued outward toward the origin of the lobulus parafloccularis. The lobulus parafloccularis is separated from the lobulus paramedianus by the fissura secunda, presents an abortive roset and then continues forward and outward as a simple folial chain which reaches the apex of the lobulus ansiformis and then turns back on itself, ending in a short uncus terminalis. Lobulus A consists of a simple series of vermal folia resting on a peduncle which extends outward in the direction of the lobulus flocularis. The lobulus flocularis appears as a definite roset and a small number of rapidly diminishing folia.

The folia of lobuli 1 and 2 and the cephalic folia of lobulus 4 are inserted into the medullary substance by means of a common peduncle. The lobulus ansiformis and lobulus paramedianus are supplied with a broad implantation into the medullary substance, the parafloccular formation being connected with the medullary substance lateral and ventral to the medullary insertion of the anterior lobe and the cephalic portion of the posterior lobe.

PHYSICAL CHARACTERISTICS OF CERCOLEPTES CAUDIVOLVULUS

The kinkajou is a small carnivorous animal with a catlike form, a small body and a relatively long neck. The eyes are situated well forward with overlapping fields of vision, and are well conjugated in their movements. The ears are quite feline and freely movable. The limbs are catlike in appearance and function, but the animal is much stronger than cats of its own size. The kinkajou is actively arboreal in its habitat, is a fearless climber and possesses a tail which is about equal to the length of its body and is actively prehensile. The fore limbs, which can be used as hands with facility, present great unilateral independence, equal to that of the lemurs with which this animal was originally placed. It possesses a long tongue which is protrudable and with which it licks up insects. The kinkajou is able to catch birds and small mammals. It is capable of great rapidity and agility of movement. Its activities are chiefly nocturnal.

NASUA RUFA (COATI)

The arbor vitae of the coati presents a relatively simple arrangement and is somewhat pyramidal in form. The fissura primaria is situated about in the middle; it is quite vertical and approaches almost directly the ventricular fastigium, which is pyramidal in form. The division by the fissura primaria and the ventricular fastigium into anterior and posterior lobes is about equal. The fissura secunda appears in the usual position low down in the posterior lobe and is in direct continuation with the axis of the medullary substance. The medullary substance presents its major portion in the anterior lobe as a rather thick, heavy mass which is continued upward as a strong process into lobulus 4. The posterior portion of the medullary substance continues upward as a well defined prolongation into lobulus C 2 which, together with ray 4, presents a U-shaped distribution of the medullary substance. The remainder of the medullary rays are slender.

THE MEDULLARY RAYS

Ray 1 consists of a single unbranched process from the ventral surface of the anterior medullary substance. Ray 2 consists of a prolongation of the medullary

substance cephalically, which gives rise to three independent branches, the first of which is quite simple, the second more extensive and subdivided and the third or dorsal branch intermediate in complexity between the first two stems. The next branch is one which resembles ray 3, but as it arises from the base of ray 4 it is considered as an integral part of ray 4. It arises close to the base of ray 4 at its junction with the mass of the medullary substance. It is arched forward as a slender fasciculus presenting only a few side-branches. Ray 4 itself is a massive prolongation upward of the medullary substance, which subdivides into four slender branches. The first two arise together and undergo a meager further division; the third is an apical branch which is divided and gives origin to only a few branches, and the fourth is a simple ray in the depths of the fissura primaria. Ray C 2 is heavy, and is a continuation upward and backward of the medullary substance of the posterior lobe. It presents a small number of cephalic

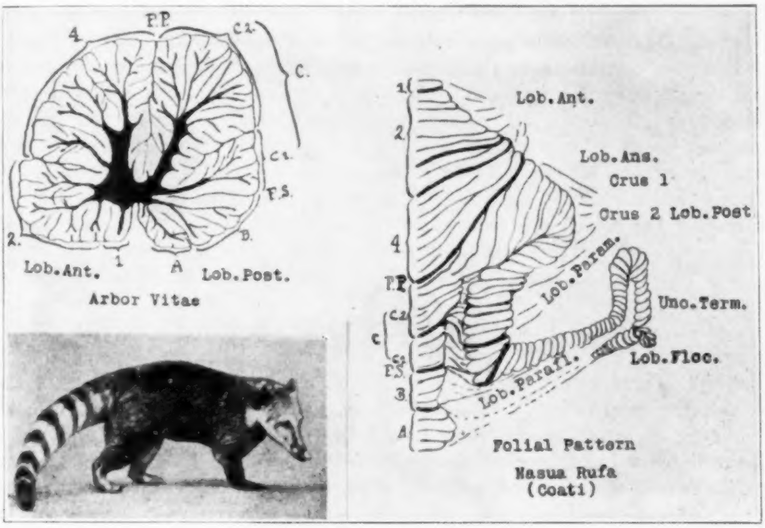

Fig. 19.—Nasua rufa (coati).

branches and divides at its summit into a spray of four branches which undergo further subdivision. The caudal surface of ray C 2 gives rise to a number of smaller branches in the depths of the fissure separating lobulus C 2 from lobulus C 1. Ray C 1 is a slender branch, a direct continuation caudally of the medullary substance which presents only a few lateral branches and ends in a simple bifurcation. Ray B is a bare caudal branch of the medullary substance which subdivides into two simple divisions. Ray A is a slender fasciculus close to the ventricular fastigium which presents only cephalic branches and a terminal bifurcation.

THE LOBULES

Lobulus 1 is composed of a simple undivided folium which forms the cephalic wall of the ventricular fastigium. Lobulus 2 is more complicated and consists of three folial groups. The first presents a single subdivided folium, the second is composed of two folial collections and the third is much more distinct and made up of two folia. Lobulus 4 presents a distinctly curved cephalic surface

and a straight caudal surface formed by the fissura primaria. It is subdivided into three chief folial groups which increase in size from before backward. The lobulus presents a considerable number of folia submerged in the fissura primaria. Lobulus C presents a rather similar reverse picture to lobulus 4, its cephalic surface being straight, and its caudal outline curved. Lobulus C 2 is much larger than lobulus C 1 and is conical in shape, the folial arrangement being rather simple and uncomplicated. Lobulus C 1 is conical in form and appears meager in its composition. Lobulus B is simple and is made up of two folial groups. Lobulus A is somewhat elongated caudally and does not possess any particular individualities.

THE FOLIAL PATTERN OF NASUA RUFA

The folial pattern presents a relatively simple type of organization. The fissura primaria starts at about the midpoint of the pattern and proceeds forward and outward. The anterior lobe is distinctly triangular in outline while the posterior lobe is simple, the vermal folial chain being straight, without any lateral deviation or curve. The fissura secunda appears in the usual position between lobuli C and B, and is continuous with the sulcus which separates the lobulus paramedianus from the parafloccular formation. Lobulus 1 consists of a single vermal folium. The folia of lobulus 2 are successively extended and arranged in a gradually increasing series with a caudal folial group which is rather distinct from the remainder of the lobulus. There is no vermal division of this lobule by secondary sulci. Lobulus 4 consists of a group of folia, eight or nine in number, at the median line which are reduced to two at the periphery. Some of the sulci are purely vermal; others extend further outward. The reduction in the number of folia forming the lateral portion of the anterior lobe accounts for the convergent direction of the sulci. Lobulus C 2 is divided into two definite portions, the cephalic group of folia being directly continuous with the vermal folia and converging on the fissura primaria, disappearing in it without reaching the periphery. There is not, therefore, a definite lobulus simplex. Following these folia which disappear in the fissura primaria, there is a series of folia, gradually diminishing in length, which form crus 1 of the lobulus ansiformis. The apex is formed by a folial roset, following which appear the folia of crus 2 which turn backward, mesially and caudally, their mesial extremities being in contact with crus 1 and thus forming a well defined sulcus intercruralis. The caudal half of the vermal portion of lobulus C 2 consists of a group of folia which are confined to the vermis, but which are continuous in the depths of the paramedian fissure, with the proximal folia of crus 2. Lobulus C 1 consists of three or four vermal folia which succeed the folia of lobulus C 2 in a direct line. These are connected with the folia of the lobulus paramedianus, as far back as the fissura secunda. The folia of lobulus B are arranged in a simple chain, and converge on a peduncle which is directed outward toward the lobulus parafloccularis. The lobulus parafloccularis is a relatively simple structure consisting of successive folia, one following the other as a definite chain. The chain turns on itself in the vicinity of the apex of the ansiform lobe, continues forward, turns again on itself and then continues backward and mesially in the form of an uncus terminalis. Lobulus A consists of four or five simple folia arranged on a peduncle which fades out in the medullary substance in the direction of the lobulus flocularis. The lobulus floccularis appears as a folial roset, with a group of successively diminishing folia situated between the peduncle of the cerebellum and the parafloccular formation.

The implantation of the various lobules is relatively simple, the first, second, third and fourth all converging on a single peduncle. The lobulus ansiformis

and the lobulus paramedianus are inserted by a converging peduncle, lateral and ventral to which are attached along the surface of the medullary substance, the parafloccular formation and the uncus terminalis.

PHYSICAL CHARACTERISTICS OF NASUA RUFA

The red coati is a small bodied carnivore combining the physical characteristics of a cat and a badger. It is actively arboreal and chiefly nocturnal. The body is rather stocky, the limbs short and powerful, the neck of medium length and the head of moderate size. The eyes are placed anteriorly, possess overlapping fields of vision and are well conjugated in their movements. The head is continued forward into a well defined proboscis which is actively movable and is used in grubbing up insects, larvae, etc. The tongue is of moderate size and is used in lapping up water. The coati descends a tree head first, regulating its descent by its hind limbs which are flexible and agile. It has a relatively long tail which does not seem to be of any particular use or function and is not prehensile.

URSUS AMERICANUS (BLACK BEAR)

The arbor vitae of the black bear presents a more or less rounded outline. The fissura primaria appears somewhat caudal to the middle of the arbor and approaches the medullary substance somewhat behind the point at which the narrow ventricular fastigium appears. It is directed somewhat from behind forward and downward, its lower extremity turning rather sharply forward. This arrangement of the fissura primaria and the fastigium divide the arbor in rather an oblique manner into the anterior and posterior lobes, the former being somewhat the larger. The fissura secunda appears below the middle of the posterior lobe, directed in the axis of the medullary substance backward and somewhat downward toward the periphery. The medullary substance appears as a rather large mass in the center of the cerebellum, not showing any particular demarcation into the medullary substance of the anterior and posterior lobes. The arbor pattern in general shows a rather extensive degree of lobulation, the medullary rays being fairly heavy with numerous subdivisions.

THE MEDULLARY RAYS

Ray 1 appears just in front of the fastigium as a simple stalk, with a few lateral branches. Ray 2 is comprised of three independent stems which arise from a heavy prolongation forward of the medullary substance. The first is directed almost immediately downward and divides into a terminal bifurcation without any side branches. The second, which is heavy, is directed forward and presents a division at its tip into three medullary twigs, which do not give off lateral branches but have terminal bifurcations. The third subdivision of ray 2 appears in a more or less semi-independent position between the base of ray 2 and the base of ray 4. It is a relatively heavy stalk, advancing upward and forward, and it gives off a prominent cephalic branch which divides into lateral twigs, and a more vertical stem which presents lateral and terminal branches. Ray 4 is a heavy stalk arising from the upper aspect of the medullary substance. It is almost vertical dividing into two heavy stems which diverge. The cephalic stem proceeds somewhat forward and upward, giving off a few simple divisions and ending in three terminal branches. The caudal stem of ray 4 is a rather heavy stalk almost devoid of cephalic branches except at its summit, while from its caudal aspect arise a considerable number of long branches which proceed backward toward the fissura primaria. A number of slender branches arise from the medullary substance in

the depths of the fissura primaria. Ray C appears as the main prolongation of the posterior portion of the medullary substance, immediately subdividing into two major stalks, rays C 1 and C 2. Ray C 2 proceeds upward and backward, giving off minor stems as it proceeds, and then divides into a cluster of branches at its summit. Ray C 1 proceeds almost directly backward, giving off a few slender lateral branches, and then divides into a group of rather extensively divided subrays. Ray B arises below the fissura secunda as a slender, simple ray, giving off lateral branches. Ray A is a simple derivative of the medullary substance, with a few side branches.

THE LOBULES

The lobules are disposed in accordance with the branches of the medullary substance already described. Lobulus 1 is simple, presenting only a small degree

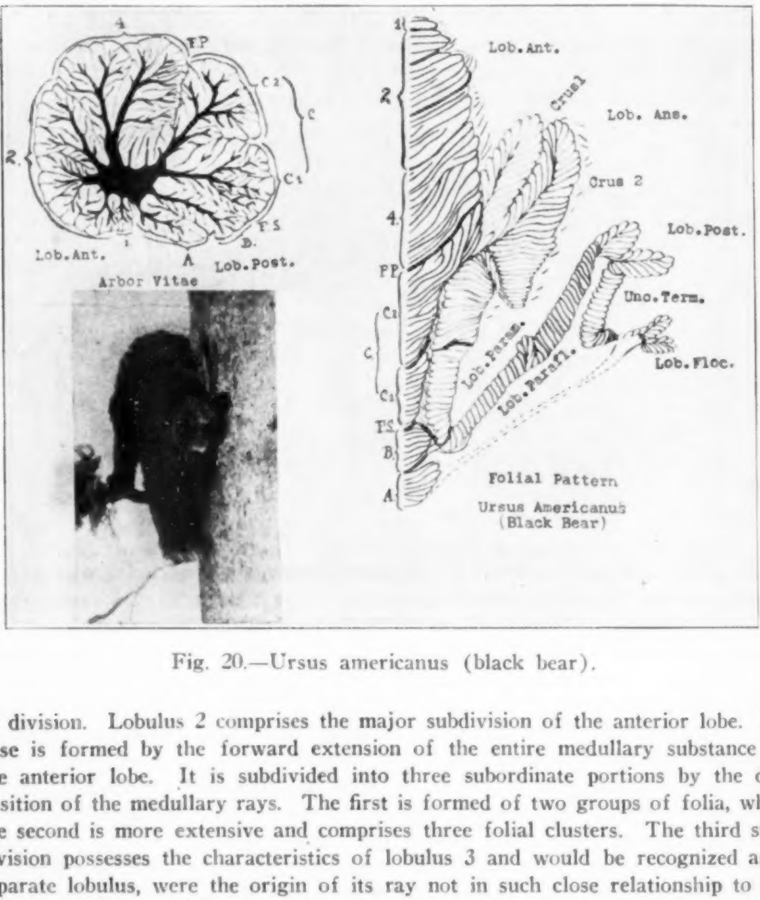

Fig. 20.—Ursus americanus (black bear).

of division. Lobulus 2 comprises the major subdivision of the anterior lobe. Its base is formed by the forward extension of the entire medullary substance of the anterior lobe. It is subdivided into three subordinate portions by the disposition of the medullary rays. The first is formed of two groups of folia, while the second is more extensive and comprises three folial clusters. The third subdivision possesses the characteristics of lobulus 3 and would be recognized as a separate lobulus, were the origin of its ray not in such close relationship to the other rays forming lobulus 2. It is composed of two groups of surface folia. Lobulus 4 is relatively conspicuous, consisting of two sublobules: the cephalic group made up of a fairly extensive series of surface folia, while the caudal collection presents a small cephalic group of folia and a series of extensive caudal branches which form the cephalic tip of the fissura primaria. Lobulus C consists

of two portions, lobuli C 2 and C 1. Lobulus C 2 is a relatively extensive lobulus forming the dorsocaudal angle of the arbor vitae, and presents a number of vermal subdivisions. Lobulus C 1 is somewhat more extensive than usual and is formed by the three-fold division of the medullary stem into an extensive apical cluster of folia. Lobulus B is formed by a compressed group of folia, consisting of only a few surface lamellae. Lobulus A is a small lobulus and is placed almost entirely in a horizontal plane.

THE FOLIAL PATTERN OF URSUS AMERICANUS

The folial pattern of the black bear presents a general appearance which is quite individual owing to the peculiar formation of the lateral extension in the vicinity of the lobulus ansiformis. The division of the folial surface into the anterior and posterior lobes due to the fissura primaria appears in the usual position. The fissure presents itself as a relatively straight furrow beginning at about the middle of the folial pattern and proceeds outward with a considerable inclination forward. The fissura secunda appears in the usual position between lobuli B and C, and in its continuation outward divides the lobulus paramedianus from the lobulus parafloccularis.

Lobulus 1 is comparatively simple, consisting of only two vermal folia. Lobulus 2 is subdivided, as is indicated in the arboreal pattern, into three portions, a narrow group of vermal folia cephalically, a relatively wider group in the second subdivision of the lobulus and a caudal group consisting of four or five folia which proceed outward converging as they approach the periphery. Lobulus 4 presents a definite subdivision into two parts: (1) a cephalic group of striplike folia extending from the median line to the lateral periphery, the caudal folium being divided at its extremity, and (2) four or five folia which converge on the fissure separating the two portions of lobulus 4. These are succeeded by a group of folia which reach the periphery. Lobulus C presents a definite subdivision into two portions, lobuli C 2 and C 1. Lobulus C 2 consists of a group of folia, the majority of which do not reach the lateral surface, but end by turning forward into the fissura primaria. This may represent the group which usually forms the lobulus simplex. The remainder appear as short, vermal folia which come to a termination in the paramedian fissure, but are continued forward in the depths of this fissure to reappear as an elongated folial roset. This is immediately followed by an even more extensively developed roset formation which appears to present some resemblance to the lobulus ansiformis, crus 1 extending outward to an apex and then returning as crus 2 which continues backward in a gradually widening series of folia. Reaching a maximum, the folia then narrow rapidly; the chain, however, at the middle of its course turns on itself in a group of submerged folia forming a roset, and then again resumes its course backward as a typical paramedian formation. These folia are apparently continuous with the caudal vermal folia of lobulus C 2. Lobulus C 1 appears as a group of diminishing vermal folia, continuous laterally with the caudal portion of the paramedian formation, which, apparently, is a group of narrow folia terminating by junction with the lobulus parafloccularis. Lobulus B appears as a group of vermal folia arranged as a roset, the peduncle of which is continued outward to the junction of the lobulus paramedianus with the lobulus parafloccularis. The lobulus parafloccularis runs directly forward and outward as a long chain of narrow folia interrupted at about its middle by a folial roset. It terminates as a double roset succeeded by an uncus terminalis which, at its termination, turns outward toward the lobulus flocculararis. The lobulus parafloccularis is in relationship with the lateral edge of the ansiform formation, the roset in the lobulus para-

floccularis fitting into the indentation between the caudal portion of crus 2 and the lobulus paramedianus proper. Lobulus A appears as a group of diminishing folia. These are based on a peduncle which is directed outward in the general direction of the lobulus floccularis. The lobulus floccularis consists of a simple chain of lamellae which develop two terminal rosets.

Lobulus 1 joins with the first division of lobulus 2 in its peduncular insertion into the medullary substance. The second division of lobulus 2 has an independent peduncle, while the third division has a peduncle in common with lobulus 4. The two extended rosets and the entire paramedian formation have a common insertion, while the parafloccular formation is connected with the medullary substance, ventral and lateral to the ansiform and paramedian lobules.

PHYSICAL CHARACTERISTICS OF URSUS AMERICANUS

The American bear is a relatively large animal about 5 feet in length and weighing about 400 pounds (181.4 Kg.). It has a heavy body, a rather large head, a thick powerful neck and short but strong limbs. The eyes are situated in the anterior position and possess overlapping fields of vision. In movement, the eyes are well conjugated. The ears are fairly large, rounded and freely movable. The limbs are powerful, and the animal is usually quadrupedal in progression, with a deliberate, flat-footed shambling gait. The bear can readily sit upright on its haunches, and it can walk upright. Under training, it can run, dance, skate and ride bicycles with the hind feet. The bear is capable of considerable speed and may even be called fleet of foot. It is a good tree climber. There is a considerable degree of unilateral independence of both the fore and the hind limbs. This is especially true of the fore limbs in digging, climbing, caring for the young and attack and defense.

PHOCA VITULINA (COMMON SEAL)

The arbor vitae of the seal shows a distinct organization of the type of carnivorous animals, with a definite division between the anterior and posterior lobes, a well defined separation of the medullary substance of the anterior and posterior lobes and a clearly marked fissura primaria and fissura secunda. The outline of the arbor vitae is relatively oval, the long diameter being directed from before backward. The fissura primaria appears well forward in the arbor vitae, and is placed more or less vertically opposite the ventricular fastigium, which is wide open, is relatively shallow and leaves a considerable extent of the medullary substance uncovered. The division into the two lobes shows a marked preponderance of material in favor of the posterior lobe. The medullary substance is definitely divided into two portions, those of the anterior and posterior lobes, by a constriction corresponding to the approach of the fissura primaria to the fastigium. The medullary substance of the posterior lobe is somewhat more extensive than that of the anterior lobe and appears chiefly as a base for the medullary rays C 2 and C 3.

THE MEDULLARY RAYS

A distinct folium is applied to the superior medullary velum which, therefore, may be termed the lingula. If this is considered the first medullary ray, the subsequent branches of the anterior medullary substance fall into subdivisions of ray 2. These appear as a double group of rays, the first of which arises as a stem derived directly from the cephaloventral angle of the medullary substance. The second group represents the chief prolongation of the medullary

substance cephalically and presents a stout base which almost at once divides into two secondary stalks, each of which is fairly heavy. These diverge somewhat, giving off lateral branches. The first of these is considerably shorter than the second which forms the apex of the anterior lobe. The second subdivision is stout and divides into two primary subdivisions which give off lateral branches. Ray 4 appears as a vertical stalk with a heavy base which at once gives rise to three separate stalks, a cephalic which proceeds forward and upward, dividing at its extremity, a middle branch which proceeds in a curve upward and somewhat forward giving off slender branches and a caudal branch which lies in the depths of the fissura primaria. Ray C consists of almost all the medullary substance of the posterior lobe, presenting a thick, heavy center from which three chief branches arise, the most cephalic of which is a vertical continuation of the medullary center dividing into two heavy

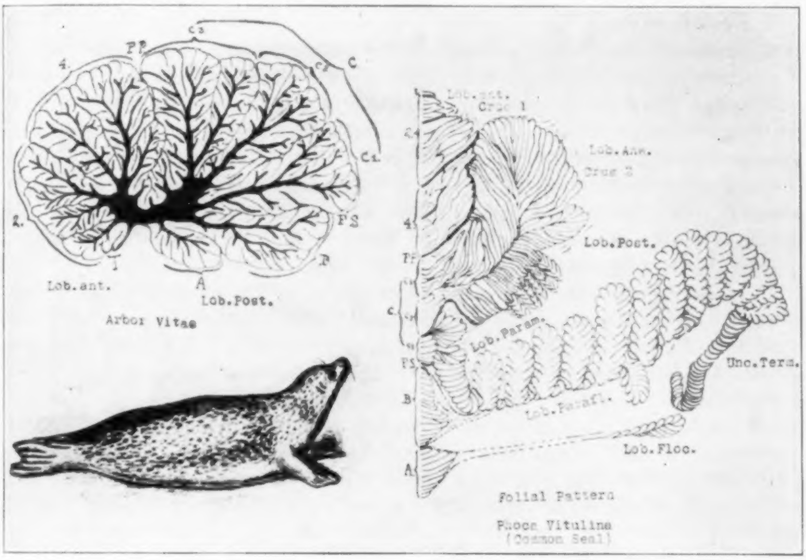

Fig. 21.—Phoca vitulina (common seal).

stalks which are extensively branched and bifurcate terminally. The middle branch proceeds directly backward and upward from the medullary center, giving off relatively heavy side branches and terminating in rather an extensive apical spray. The third stalk arises almost horizontally from the base of ray C, gives off lateral branches of considerable size and terminates by dividing into three subrays. Ray B is a large stalk which arises below the center of the posterior lobe, is directed almost backward, and divides into two branches. Ray A is a slender stalk arising from the ventral surface of the medullary substance of the posterior lobe and turns backward under cover of ray B.

THE LOBULES

The lobulation of the arbor vitae depends on the subdivision of the medullary substance. Lobulus 1 consists of a single folium lying directly on the superior medullary velum, thus forming a lingula. Lobulus 2 consists of three folial

groups which arise from the medullary center, the first two being narrow folial groups while the third is somewhat more extensive, presenting two distinct folial collections. Lobulus 4 is well developed and is formed by two folial groups which show a relatively rich degree of subdivision, with a considerable development of branches in the depths of the fissura primaria. Ray C forms the chief division of the posterior lobe and consists of three groups of folia which show a characteristic appearance in the folial pattern. In the arbor vitae the most cephalic is the most extensive, presenting two definite and considerable subdivisions; the second and third subdivisions are not so extensive as the first. Lobulus B is fairly well defined, divided into two chief groups of folia. Lobulus A is a well developed folial cluster forming the caudal margin of the fastigium.

THE FOLIAL PATTERN OF PHOCA VITULINA

The seal presents a considerable divergence from the general type of folial arrangement in carnivorous animals, in the organization of the folial pattern. In the first place, the folia are fine; the sulci separating them are wavy and broken, and many of them appear to wander about the folial surface without any definite direction, a number turning backward almost at right angles to the general direction of the folia. There is a distinct tendency in the anterior lobe to form a vermis with definite lateral portions which faintly resembles the cetacean type of anterior lobe. The fissura primaria appears somewhat cephalad to the midpoint of the folial pattern, so that the posterior lobe is considerably more extensive than the anterior lobe. This is due to the relatively large development of the lobulus ansiformis and to the remarkable and characteristic arrangement of the paraflocculus. The fissura secunda separates lobuli B and C and the lobulus paramedianus from the lobulus parafloccularis. Lobulus 1 appears as a single folium lying on the superior medullary velum as the lingula. Lobulus 2 presents a definite subdivision into two portions. The cephalic part consists of three vermal folia subdivided at the midline. The caudal portion presents a definite development of the lateral portion of the anterior lobe but also shows clear indication of a vermian differentiation, the folia increasing in their lateral extent. Lobulus 4 is a peculiar lobulus formed of wavy lines presenting a definite subdivision into cephalic and caudal portions and a clear separation into vermal and lateral contingents. The vermal division is formed of short sulci arranged in a rather aimless manner with a lateral portion which is more regular but still shows a somewhat sinuous type of folial division. None of the folia of lobulus 4 reach the periphery on account of the marked forward extension of lobulus C which hems in the lateral part of lobulus 4. Lobulus C presents three definite divisions in the folial pattern, corresponding to those of the arbor vitae. The most cephalic, lobulus C 3, is composed of a group of folia which disappear in the proximal portion of the fissura primaria, a very rudimentary lobulus simplex. The second portion, lobulus C 2, presents a distinct vermal distribution, the folia converging on a peduncle which is continued outward into what apparently is the sulcus intercruralis. The lateral folia of lobulus C 2 are apparently connected with the deep folia of the caudal portion of C 2 and continue outward as a sinuously arranged chain of lamellae which gradually turns forward, curving constantly inward, however, so that the peripheral terminations are in contact with the fissura primaria and, therefore, with the folia of lobulus 4 and of lobulus 2. These continue forward as crus 1 until they reach a point opposite the middle of lobulus 2 where

the apex of the ansiform formation appears; crus 2 then develops as a group of folia continuing backward and inward, forming a sulcus intercruralis. In the middle of crus 2, a well defined folial roset appears. The succeeding portion of crus 2 develops a peculiar method of implantation into the medullary substance which will be described later, the caudal folia of crus 2 apparently coming into connection with the lobulus C 2. Between lobuli C 2 and C 1, there appears a definite extrusion from the vermis of a folial roset which is interposed between the termination of crus 2 and the lobulus paramedianus itself. The peduncle of this roset is apparently connected with the submerged folia in the fissure between lobuli C 2 and C 1. Lobulus C 1 appears as a group of vermal folia from which there issues outward a peduncle on which develops a folial roset which straightens out into a group of folia forming the lobulus paramedianus proper.

Lobulus B consists of a group of vermal folia, the cephalic half of which consists of narrow folia, and the caudal half of much wider folia. These folia converge on a peduncle which is directed outward and apparently is connected with the base of the lobulus parafloccularis. The lobulus parafloccularis is a remarkable structure consisting of a series of much elongated folial rosets, which closely succeed one another. At about the middle of the lobulus parafloccularis, there is one which is directed in an axis opposite to that assumed by the remainder. This group of folial rosets continues outward along the course of crus 2 to the apex of the ansiform formation, where it turns back on itself still as a series of rosets, and then terminates in a long drawn out uncus terminalis with a recurved tip of its own. This parafloccular formation is applied along the under and outer surface of the remainder of the posterior lobe. Lobulus A consists of a group of folia, at first short, which rapidly increase in width and then dwindle down to a small folium which is hidden in the depths of the fastigium. This is based on a peduncle which is continued outward in the general direction of the lobulus floccularis. The lobulus floccularis is a relatively simple structure consisting of a row of folia which expands into a folial roset. It appears in the usual position between the peduncle of the cerebellum and the lobulus parafloccularis.

The implantation of the various lobes of the medullary substance presents the following arrangement: Lobulus 1 is implanted on the superior medullary velum as a lingula. Lobulus 2 has a distinct and independent implantation through a peduncle of its own. The implantation of lobulus 4 is hidden in the depths of the fissura primaria by the overgrowth of lobulus C. The ansiform formation, as far as the middle of crus 2, possesses a broad implantation in the medullary substance. The intermediate portion of crus 2 presents a peculiar lateral implantation in the development of a series of folial stalks, producing elongated rosets which are continuous with two or more of the transverse folia of the middle portion of crus 2. Each of these folial groups or rosets has a separate implantation into the medullary substance along the lateral margin of the paramedian and ansiform formations. The paraflocculus possesses a broad implantation for its serial group of rosets ventral and lateral to the implantation of the remainder of the posterior lobe.

PHYSICAL CHARACTERISTICS OF PHOCA VITULINA

The form of the seal shows a marked divergence from that of other carnivorous animals, directly dependent on its assumption of an aquatic habitat. The body is large and flat; the neck is relatively short but mobile, and the head is small with the eyes placed intermediately between the anterior

and lateral positions. The eyes possess overlapping fields of vision and they are well conjugated. The tongue is moderately long and can be protruded to a considerable extent. The limbs are reduced to flippers for the sake of progression through the water, the fore limbs being capable of supporting the animal to a certain extent, but its progression on land is difficult and ungainly, being accomplished by a series of jumps. The posterior limbs are drawn out into flippers and are practically incorporated with the tail into a structure used only as a propulsive organ. The animal occupies an aquatic habitat in which its entire body is supported by the water, and when on land the ventral surface of the body rests on the ground, so that the limbs act little as a means of raising the body from the supporting surface, and are propulsive almost entirely and not supporting organs. The needs of this animal in equilibration, therefore, are relatively insignificant, while its requirements for coordinated activity of its entire axial musculature are enormously increased by the fact that the mode of propulsion is fishlike, the body, hind limbs and tail acting as successively coordinated parts of a propulsive wave, while the fore limbs serve simply to direct the body and determine the position of the head near the surface of the water.

OTARIA GILLESPIEI (CALIFORNIA SEA LION)

The arbor vitae of the California sea lion clearly indicates definite characteristics of the carnivora. It is more or less oval in outline. The fissura primaria appears in a position somewhat cephalad to the middle of the arbor vitae. It is chiefly vertical turning somewhat forward in the depths of the fissure to approximate the medullary substance opposite the ventricular fastigium which is relatively narrow. The posterior lobe predominates in the median section, being more extensive than the anterior lobe. The fissura secunda appears in the usual position between lobuli B and C and lies in the general axis of the medullary substance of the posterior lobe. The medullary substance of the anterior lobe is collected in the center as a condensed mass of white matter which in passing into the posterior lobe becomes drawn out chiefly to form ray C. In general, the structure of the arbor vitae is rather delicate, the lobulation is rather extensive and the medullary rays are relatively light, except ray C, which is a heavy caudal extension of the medullary substance.

THE MEDULLARY RAYS

Ray 1 appears as a lingular formation lying directly on the superior medullary velum. It resembles a tongue-like protrusion from the medullary substance of the anterior lobe. Ray 2 appears from the cephalic portion of the medullary substance as an independent stem which presents a number of lateral branches. Ray 3 arises from the cephalodorsal angle of the medullary substance as a long slender ray which proceeds forward giving off numerous subdivisions. Ray 4 is a relatively slender ray passing upward and giving off lateral branches. One of these is a relatively strong stem which proceeds forward and divides into two branches which are extensively subdivided. The caudal portion of ray 4 is heavier and gives off short but thick cephalic branches, while the caudal twigs are long and slender, and form the cephalic margin of the fissura primaria.

Ray C is the chief caudal continuation of the medullary substance, presenting a long drawn-out stalk which proceeds as a thick stem upward and backward. It appears as a thick, heavy ray which gives rise to a considerable number of branches, the most caudal of which have a peculiar arrangement

as successive transverse laminae, corresponding to the folding under of the caudal portion of lobulus C 2 as seen in the folial pattern. Ray C 1 arises as a long slender branch, from the under surface of ray C and proceeds backward giving off lateral branches. Ray B arises from the lower and caudal angle of the medullary substance as a relatively well defined stalk giving off lateral branches and ending in a bifurcation. Ray A appears as a heavy stem arising from the under surface of the medullary substance immediately caudal to the fastigium, at once giving rise to two terminal branches.

THE LOBULES

Lobulus 1 appears as a lingular group of folia arising from the superior medullary velum. Lobulus 2 consists of successive folia of small size, except

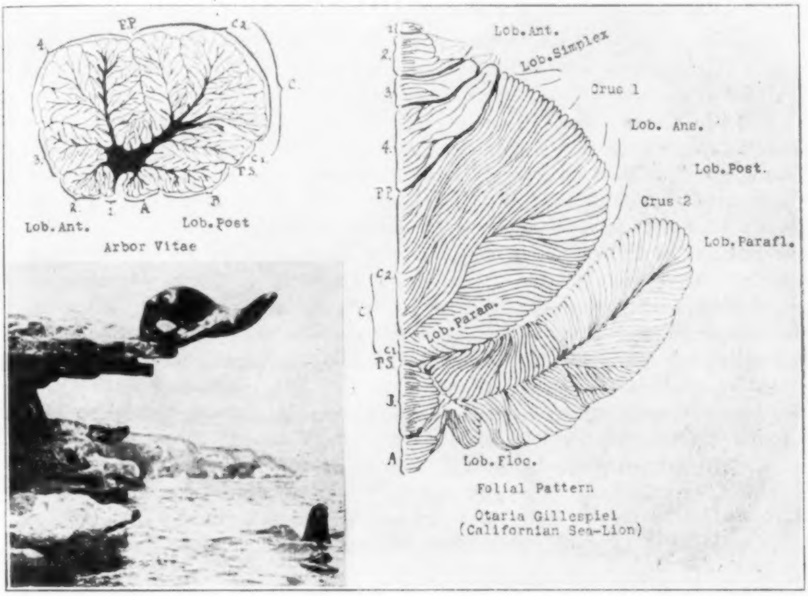

Fig. 22.—Otaria gillespiei (Californian sea lion).

the last which is coarser. Lobulus 3 is considerably larger than the preceding lobulus, presenting a number of surface folia. If lobulus 3 should be incorporated with either lobulus 2 or lobulus 4 it appears as more closely associated with the former than the latter. Lobulus 4 is considerably more extensive and presents two subdivisions. The cephalic group presents a rather extensive surface disposition and is subdivided into two folial groups. The caudal group does not possess so great a surface expression but presents a rather extensive development of folial groupings in the formation of the cephalic wall of the fissura primaria. Lobulus C 2 presents a greatly expanded surface, the folia being arranged in three definite subdivisions. The first group is formed by a fairly narrow set of folia, the second group is distinctly conical, the free surface being formed by an expanded spray of folia and the third group is arranged as a series of folial layers—long slender laminae which have few lateral branches, and indicate a rather extensive underfolding of the caudal

lamellae of lobulus C 2. Lobulus C 1 appears as a slender lobulus with a small number of surface folia. Lobulus B has a considerable surface extent, each folium showing a subsidiary sulcus, the ventral folia being more higly developed than the dorsal lamellae. Lobulus A is noteworthy as it is considerably more condensed than usual.

THE FOLIAL PATTERN OF OTARIA GILLESPIEI

The fissura primaria is a well defined fissure appearing well forward in the folial pattern demarcating an anterior lobe which is markedly subservient in extent to the area of the posterior lobe. The latter has developed out of all proportion owing to the enormous expansion of the ansiform formation and the paraflocculus. The fissura secunda appears separating lobulus B from lobulus C and is relatively short on account of the fact that the lobulus paramedianus is directly continuous with the vermal folia at this point. Lobulus 1, representing the lingula supported by the superior medullary velum, presents only a single folium subdivided laterally into three small serrations. Lobulus 2 presents a number of parallel folia transversely disposed, the cephalic being vermal while the caudal three present lateral extensions. The majority of these folia are subdivided in the midline. Lobulus 3 presents a fairly regular arrangement of the sulci in its vermal portion which become irregular in the hemisphere. The folial arrangement of lobulus 3 shows that it is more closely related to lobulus 2 than to lobulus 4. The first two sulci diverge from one another and come to an end, while the caudal three are joined together and fail to join the sulcus between lobuli 3 and 4, so that the lobulus which is subdivided into a considerable number of folia in the arbor vitae is reduced to a single thick folium at the periphery. Lobulus C consists of two separate subdivisions forming lobulus C 2 and lobulus C 1. Lobulus C 2 is much more extensive than lobulus C 1 and presents but little indication of a division into vermal and lateral portions. The sulci run, in general, a regular course, forming narrow folia which begin in the vermal region and extend outward for a variable distance. Lobulus C 2 presents five separate subdivisions, all of which begin as folia which run obliquely forward converging on a preceding sulcus. The successive folia then extend further and further outward until the caudal folia of each subdivision reaches the periphery. Except for this arrangement there is little indication of a differentiation between vermal and hemispheral portions. The folia forming the hemispheral portion are long and narrow and regularly arranged, and correspond with what may be termed crus 1 of the ansiform formation; they succeed a few folia which are arranged in a manner suggestive of the lobulus simplex. The lobulus ansiformis presents a slow gradual curve outward and an ill defined apex, following which the folia arrange themselves in a diminishing series returning toward the midline, the mesial terminations of the folia of crus 1 and crus 2, forming a definite sulcus intercruralis. The folial chain gradually diminishes in lateral extent, forming a lobulus paramedianus which becomes continuous with the vermal folia of lobulus C 1. The folia of lobulus C 1 continue to diminish, becoming relatively insignificant and are caudally limited by the fissura secunda.

Lobulus B presents a considerable group of folia, all of which are subdivided at the midline. These converge to form a folial roset based on a peduncle which extends outward, apparently continuous with the middle of the parafloccular formation. The lobulus paraflocculars shows a definite connection with the caudal folia of the lobulus paramedianus, and continues outward

as a regular folial chain of considerable lateral extent. When it reaches a point beyond the apex of the lobulus ansiformis it slowly returns on itself, the folia forming a definite interparafloccular sulcus. This returning group of folia is interrupted at its midpoint by a marked irregularity in the arrangement of the folia owing to the formation of a group of ill defined and abortive rosets. The regular arrangement returns, as the chain approaches the base of the lobulus paraflocculus which is apparently continuous with the peduncle of lobulus B. Lobulus A consists of a series of diminishing vermal folia. The folia of lobulus A converge on a peduncle which is in apparent connection with a simple group of folia arranged as a single roset which forms the lobulus flocculаris, overshadowed by the parafloccular formation which lies over its base.

Lobuli 1, 2 and 3 present independent peduncular insertions into the medullary substance. The much expanded ansiform formation presents a wide single implantation, while the parafloccular formation is attached ventrally and laterally to the preceding lobulus.

PHYSICAL CHARACTERISTICS OF OTARIA GILLESPIEI

The California sea lion presents a long, narrow, sinuous body, with an extended mobile neck, on which is supported a small head with a pointed nose. The eyes are situated in the anterior position, possess overlapping fields of vision and are well conjugated. The limbs are short, being capable of a limited and awkward use for locomotion. On land, the hind limbs are folded forward to support the rear of the body. The incorporation of the hind limbs and tail is not complete. The fore limbs present definite supportive characteristics, the distal portions of the limbs being converted, however, into flippers. The sea lion possesses a marked degree of agility and coordinative organization in its movements. The ability of the animal to catch articles thrown to it and to balance objects on its head is well known to those who have frequented any of the circuses. In fighting, the head of the sea lion is darted from side to side, and backward and forward, with great speed, and when the occasion appears the jaws close tenaciously on its adversaries. The tongue is of moderate size and is protrudable to a limited extent.

There is a considerable degree of unilateral independence in the fore limbs, and the animal is capable of a high degree of training and development. It possesses, in common with the seal, the characteristics acquired through its aquatic habitat, that is, the sinuous activity of the entire neck, body and limbs in progression through the water, the degree of axial coordination and integration being extreme, as evidenced by its remarkably smooth and graceful movements in water. While in the water it possesses a relatively simple degree of equilibratory needs; nevertheless, in its progress on land, where the limbs act as usual supports, there is a considerable need for this. It is capable of proceeding at a fair degree of speed on the surface of the ground.

ODOBAENUS (WALRUS)

The chief alteration in the arbor vitae of the walrus as compared with *Otaria* is the increase in the size and thickness of the medullary outgrowths which present a much more outspoken and definite pattern in the arbor vitae. The general outline of the arbor vitae is not so nearly oval as in the other pinnepedia, there being a considerable increase in the vertical depth of the section. There is an extensive increase in the richness of the subdivisions of the

medullary rays and in the foliation, and the delicacy of organization found in *Otaria* has given place to a marked coarseness of ray and folium. The fissura primaria is situated more or less in the usual median plane of the arbor vitae showing a tendency to an oblique direction forward and downward at its termination as it attempts to approach the fastigium which is situated relatively far forward. The posterior lobe again exceeds the anterior lobe, chiefly through the caudal extension of rays C 1 and C 2. The fissura secunda is in about the usual position between lobuli B and C directed from before downward and backward. The ventricular fastigium is relatively advanced, fairly wide open, deep and based directly on the medullary substance. The medullary substance is disposed chiefly as a mass in the central core of the anterior lobe. It presents a marked extension vertically into ray 4. The medullary substance of the

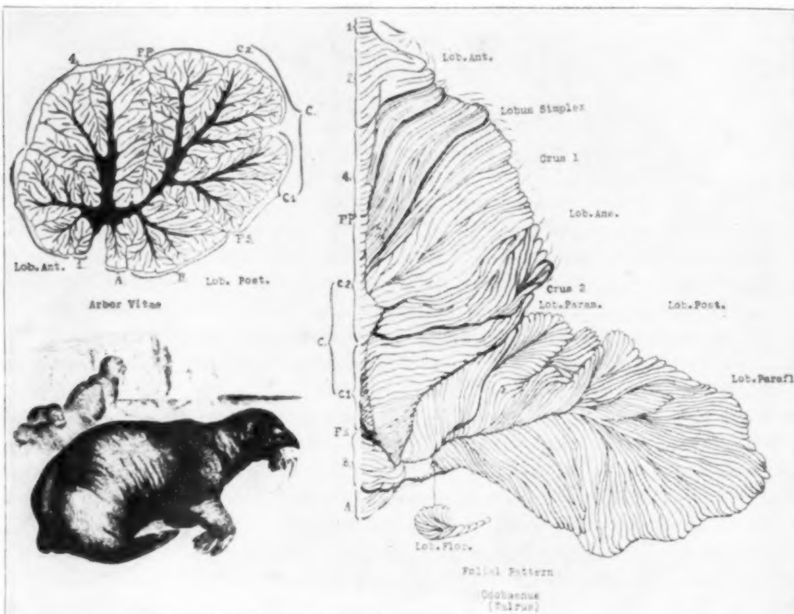

Fig. 23.—Odobaenus (walrus).

posterior lobe is disposed as a narrow caudal extension from the mass of white matter in the anterior lobe and is drawn out caudally and dorsally as a long crescentic ray C 2. There is only a small condensation of the medullary substance in the center of the posterior lobe.

THE MEDULLARY RAYS

Ray 1 appears in the form of a lingula based directly on the superior medullary velum, from which arise a series of short, delicate branches. Ray 2 consists of a considerable extension forward of the anterior medullary substance as a thick stalk which immediately subdivides into two portions, a smaller ventral stem and a much more extensive dorsal branch. The slender ventral branch proceeds downward and forward, giving off lateral twigs, and subdivides

terminally. The dorsal stem is a thick, heavy branch proceeding directly forward and giving rise to a number of small slender ventral branches, and a series of much heavier branched dorsal stems, and terminates in a rather heavy bifurcation. Ray 4 is a large, heavy stalk which arises directly opposite the ventricular fastigium and proceeds almost vertically upward, giving off a number of simple cephalic branches. It then divides into two chief branches, the cephalic at once giving off a major subdivision which proceeds directly forward giving off a series of lateral shoots. The more vertical continuation of the cephalic branch of ray 4 proceeds upward and forward, giving off lateral branches and subdividing. The caudal primary division of ray 4 proceeds upward as a heavy stalk, with short, cephalic, and long slender caudal branches; the great majority of the latter terminate in a bifurcation and form the cephalic wall of the fissura primaria. Ray C appears as a direct continuation backward and upward of the posterior medullary substance. It is a relatively thick, curved stalk, giving off a major caudal subdivision, ray C 1. Ray C 2 continues upward as a heavy stem, dividing into cephalic and caudal divisions which subdivide a number of times, the latter much more extensively than the former producing a relatively complicated lobulus C 2. Ray C 1 proceeds directly backward, giving off a few side branches, and then divides into a dorsal more extensive and a ventral less extensive stem. These continue to give rise to a considerable number of lateral branches. Ray B arises at right angles to the general course of the posterior medullary substance as a relatively heavy stalk which divides into two primary branches. These two primary divisions give off numerous lateral shoots. Ray A arises as a thick stalk close to the fastigium, and gives off lateral branches.

THE LOBULES

Lobulus 1 appears as a lingula composed of a number of folia which are supported directly by the superior medullary velum. Lobulus 2 is fairly complicated and quite characteristic. It is composed of two groups of folia. The ventral group is much less extensive and forms a conical sublobulus which presents further subdivision into two lamellar clusters. The dorsal sublobulus is rather more complicated, owing to the development of a series of fairly prominent dorsal stalks all of which give rise to a number of lateral twigs. The apex of this sublobulus is formed by the terminal divisions of the ray and is composed of two groups of laminae. Lobulus 4 is quite large and is subdivided into three folial subgroups by the division of the cephalic ray into a cephalic and a dorsal branch. The caudal division of the lobulus does not possess an extensive surface disposition, but is characteristic through the long series of caudal rays, each of which forms a folial group in the cephalic wall of the fissura primaria. Lobulus C is prominent and rather complex. It is composed of two chief folial groups, lobuli C 2 and C 1. Lobulus C 2 presents a rather extensive surface disposition and can be divided into two groups of folia, the caudal being the larger and forming a protrusion at the dorsocaudal angle of the arbor vitae. The most caudal branch of C 2 is doubled and submerged, its lateral expansion being clearly recognizable in the folial pattern. Lobulus C 1 is much larger than that of *Otaria* and is divided into a dorsal group, which is further differentiated into two subgroups, and a ventral group, which shows the same type of division but not so extensively. This group of folia is entirely submerged from the surface by the mesial extension of the hemisphere. Lobulus B is also larger and is divided into two definite folial divisions both of which are composed of folial subgroups. Lobulus A is relatively simple and forms the caudal wall of the ventricular fastigium.

THE FOLIAL PATTERN OF ODOBAENUS

A considerable degree of difficulty is encountered in analyzing the folial pattern on account of the fact that the folia of the vermis are not directly continuous with those of the hemisphere. The presence of a definite, distinct paravermian fissure, through which it is difficult to trace the connection of the vermal and lateral portions of each folial group, adds to the complexity of the folial pattern. Another factor which makes it difficult to distinguish between the relative connections and identity of the various portions of the lateral hemisphere is that the groups of folia forming the lateral extension from the vermal region seem to fuse extensively. These areas of fusion are particularly marked at the approach of the folia to the vermal region and also at the periphery of the hemisphere. There cannot, therefore, be a clear and definite distinction between the folia forming the lateral lobular masses. The fissura primaria appears considerably cephalad to the middle of the folial pattern and continues sharply forward, then swings laterally into the hemisphere, demarcating a small anterior lobe and an enormously developed posterior lobe. The fissura secunda appears in the usual position between lobuli C and B, and is drawn sharply backward into a relatively long drawn-out elbow which apparently limits the paramedian formation and indicates the transition into the parafloccular development.

Lobulus 1 appears in the form of a lingula, based directly on the superior medullary velum. It consists of three small vermal folia. Lobulus 2 presents a definite division into a vermal and a lateral portion, many of the vermal sulci extending only for a short distance and tending to converge forward, thus cutting off a definite vermal from a distinct lateral portion, and establishing a paravermian sulcus. The lateral extensions increase from before backward, the group of folia in the most cephalic portion of lobulus 2 converging to form a single lateral folium which proceeds considerably outward from the midline. The second group of folia continues even further, being reduced in number as they approach the periphery until they consist of a single broad folium. The caudal portion of lobulus 2 presents a distinct division into a vermal part marked off by a paravermian furrow from a lateral portion which appears as a broad folium subdivided into three folia by the appearance of two lateral sulci. Lobulus 4 consists of a definite division into a vermal and a lateral portion, with the well defined development of a paravermian sulcus. The vermal folia are relatively wide, the sulci separating them tending to run outward and then forward, disappearing in the paravermian sulcus. The folia of the lateral portion of the lobulus then appear as almost independent folia. They are much narrower, but about as numerous, so that their surface representation is much less than that of the lobulus in the arbor vitae. Lobulus C is divided into two definite portions, a more extensive cephalic and a less extensive caudal division, corresponding to lobuli C 2 and C 1. Lobulus C 2 consists of a chain of vermal lamellae which shows a tendency to widen and then narrow again toward the caudal portion of the lobulus. The connections with the hemispheral folia are again indistinct on account of the paramedian sulcus. The folia of the cephalic portion of lobulus C 2 are thin, well defined parallel lamellae which continue forward and outward, gradually decreasing in number. Toward the middle of the cephalic portion of lobulus C 2, a peculiar abortive roset formation appears, which protrudes outward from the median line. This roset apparently develops from a submerged folium seen in the arbor vitae in the depths of the fissure separating the two portions of lobulus C 2. The group of folia extending forward from the cephalic portion of

lobulus C 2 are rather simply arranged and, appearing directly caudal to the fissura primarius, may correspond to the lobulus simplex. The folia succeeding the distinct sulcus which limits the lobulus simplex caudally begin to show some irregularity; the folia appear to run obliquely and the impression of a sulcus intercruralis is produced, thus indicating a rather poorly defined crus 1. The succeeding folia become still more irregular, particularly the terminal folia of lobulus C 2, which apparently correspond to the submerged folia seen in the arbor vitae between lobuli C 2 and C 1 that emerge from the sulcus and participate in the folial pattern. These lateral folia may represent crus 2. Toward the caudal termination of this group of folia the arrangement becomes much more irregular, and a roset formation appears. The vermal folia of lobulus C 1 form a group submerged beneath the surface and out of sight unless the overhanging mesial termination of the folia forming the lateral expansion of C 1 is withdrawn from the midline. They then appear to be a group of small folia gradually increasing in size toward the caudal portion of the lobulus, forming a definite sulcus paramedianus. The folia disappear into this sulcus and then emerging turn mesially to form the overhanging margin which hides the vermal folia from sight. From this overhanging margin the folia pass outward, their lateral terminations turning forward. They decrease in width and form a long drawn-out termination. This entire formation is apparently the lobulus paramedianus and is limited by the lateral portion of the fissura secunda. Lobulus B appears as a fairly simple chain of lamellae, of considerable width and showing a tendency to swing forward at their lateral terminations with an indication of a roset formation caudally. Lobulus B is continued laterally as a massive peduncle which flares out into the lobulus parafloccularis. This is a large and irregularly developed structure. It forms a considerable portion, at least a third—if not a half—of the cerebellum. It occupies the entire ventral aspect of the cerebellum. The folial chain begins at the termination of the lobulus paramedianus and continues outward as a series of folia which presents three large extensive roset formations. Following this the folia become longer and longer, turn somewhat caudally at their tips and then are continued as a series of long, well defined folia, returning on the course they have already followed in the formation of the first series of folial groups. These gradually decrease in length and converge on the bare medullary stalk, which is of considerable size and is continuous with the base of the vermal portion of lobulus B. Lobulus A presents a relatively simple formation of a roset, the cephalic folia being submerged beneath the surface within the depths of the fissure between lobuli A and B. From the peduncle of this roset there is an ill defined line of connection extending outward beneath the root of the paraflocculár formation to the lobulus flocculáris which is hidden from sight by the root of lobulus parafloccularis. The flocculus is produced by a row of folia which gradually increase in size and form a definite terminal roset.

A single implantation appears for the first and second lobules, with a single small peduncle for the lateral portion of the fourth lobulus, while the lobulus simplex and the rest of the lobulus ansiformis are inserted by a broad base into the medullary substance, lateral and ventral to which is applied the entire parafloccular formation.

PHYSICAL CHARACTERISTICS OF ODOBAENUS

The walrus is a large animal with a heavy body measuring from 10 to 12 feet in length, weighing a ton. It has four extremities, the fore limbs being similar to those of the sea lion, and the posterior limbs a compromise between

those of the sea lion and the seal, possessing apparently less independence than those of the sea lion and more independence than those of the seal. The walrus can grasp and hold the prow of a boat with both fore flippers and drive his tusks through the planking. The tail is concealed between the hind limbs. The body is raised somewhat from the ground by the fore limbs, which act both as a means of progression and as a support. The head is small but heavy, the neck is short, thick and massive and the eyes are placed laterally but turned forward so that the visual fields are overlapping. The eye movements are conjugated. The lips are mobile and can be retracted. The tongue is large and fairly mobile. The tusks are used for digging out mollusks and also to aid the animal in climbing. The walrus is thoroughly at home in the water and possesses extremely finished movements in swimming and playing in the water. The animal is incapable of extensive movement on land, the limbs being poorly differentiated as a means of progression on a solid medium. There is a slight degree of unilateral independence of the limbs.

CASTOR CANADENSIS (BEAVER)

The median section of the arbor vitae of the beaver presents a more or less oval outline, the long diameter of which is directed from before, backward and upward, the irregularity in outline being due to the development of lobulus C 2. The division into two lobes by the fissura primaria and the ventricular fastigium shows that the anterior lobe is of considerably less extent than the posterior lobe. The fissura primaria is directed from before backward and downward and does not directly approach the fastigium, which is broad and wide open. The disposition of the medullary substance is in the direction of the axis of the cerebellum, from before, obliquely backward and upward. The major portion of the medullary substance lies cephalad to the approach of the fissura primaria to the medullary substance, although, strictly speaking, a line drawn from the termination of the fissura primaria to the limit of the fastigium would leave only a small proportion of the medullary substance in the anterior lobe. The medullary substance from which the cephalic stems arise is apparently more extensive than that from which the caudal rays arise, the posterior medullary substance being drawn out into a tail-like prolongation which forms the major portion of ray C 2. The fissura secunda is in the usual position between lobuli B and C and passes almost directly caudally from the medullary substance.

THE MEDULLARY RAYS

Ray 1 arises as a single stem from the ventral aspect of the anterior medullary substance and is undivided. Ray 2 arises as a rather stout stem dividing into two groups of smaller branches, the dorsal ray giving rise to two divisions. Ray 3 is a long, slender ray directed upward and forward, giving off side branches and dividing at its summit. Ray 4 is a rather stout stem arising from about the midpoint of the medullary substance. It is directed upward and forward, presenting a single division and giving off a few small side branches. The division of the medullary rays of the posterior lobe presents a rather unusual arrangement which makes it difficult to determine exactly the identity of the various branches. A consideration, however, of the division of the arbor vitae, together with the folial pattern, makes the identity of the individual branches relatively clear. Ray C really represents the caudal extremity of the medullary substance and gives off an independent ray C 1 which apparently arises without any direct connection with ray C 2. Ray C 2 is a direct caudal prolongation of

the medullary substance, a relatively thick stem which divides into three or four caudal branches, the first two being almost horizontal, while the final divisions consist of a pair of slender, almost vertical branches, the cephalic branch giving off a group of branches which form the caudal wall of the fissura primaria. There is also connected with ray C 2 a rather prominent folium in the depths of the fissura primarius. Ray C 1 is given off from the main mass of the medullary substance opposite the depths of the fissura primaria. It continues back as a simple stalk, giving off side branches. Ray B arises in front or just below the origin of C 1 as a slender stem which immediately divides into two branches that give off numerous twigs. Ray A arises close to the fastigium as a slender branch directed downward and backward, giving off several smaller branches.

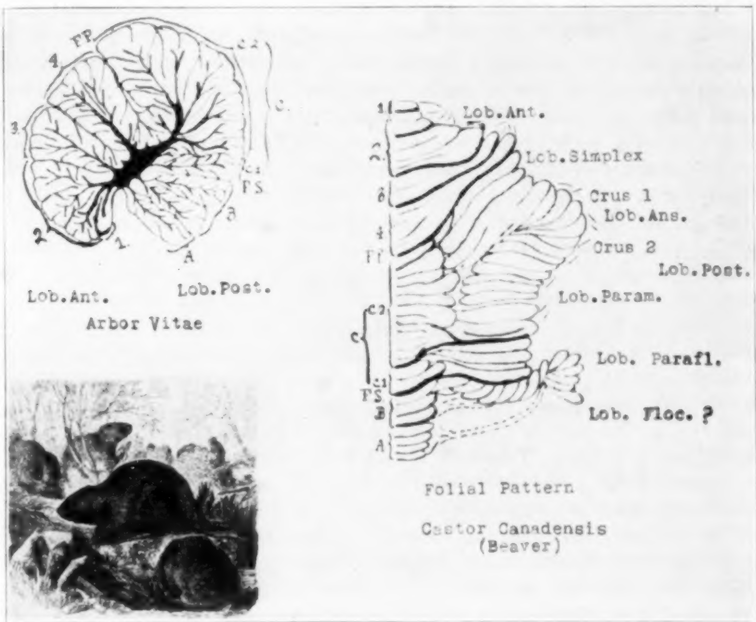

Fig. 24.—Castor canadensis (beaver).

THE LOBULES

Lobulus 1 appears as a single simple folium which forms the cephalic wall of the fastigium. Lobulus 2 is of fair size and subdivided into a smaller ventral and a larger dorsal portion. These are simply arranged and consist of broad folia without much secondary division. Lobulus 3 is narrow, consisting of two surface folia with one small subdivision. Lobulus 4 is somewhat more extensive, presenting on the surface two chief folia which are subdivided by short sulci. Lobulus C presents two portions which are distinctly different in their folial arrangement. Lobulus C 2 is a large extensive group of folia. It is subdivided into a considerable number of subsidiary folial groups. The first of these presents a number of folia in the depths of the fissura primaria while caudally it is much reduced. There then succeed three groups of folia which approach the horizontal plane, each folium possessing a medullary ray

which arises independently from ray C 2. Lobulus C 1 is a much reduced narrow lobulus and presents on the surface only two small folia. Lobulus B presents a definite division into two portions which possess a rather simple folial arrangement. Lobulus A is a simple folial group.

THE FOLIAL PATTERN OF CASTOR CANADENSIS

The fissura primaria arises at a point somewhat cephalad to the middle of the folial pattern and proceeds in a simple curved fashion forward and outward to the periphery. The fissura secunda is a definite fissure in the folial pattern of the beaver and supplies an unmistakable separation between lobuli B and C and the lobulus parafloccularis and the lobulus paramedianus. It appears in its usual position between lobuli C and B and is continued directly into the hemisphere on account of the fact that the folia of the lobulus paramedianus are continuous with the folia of the vermis in this portion of the posterior lobe. Lobulus 1 consists of a single vermal folium. Lobulus 2 is formed by a cephalic group of vermal folia and a caudal group made up of two wide folia which present lateral extensions and are subdivided for the most of their extent into four minor folia, reduced at the periphery, however, to two folia. Lobulus 3 arises as a divided folium which, however, is continued as a long narrow lamina. Lobulus 4 presents definite vermal divisions into four small folia which consolidate by the disappearance of the sulci into one long lamella. Lobulus C is divided into a complicated cephalic and a simple caudal portion. The cephalic division is lobulus C 2 and consists of parts representing vermal and lateral subdivisions. The vermal folia consist of a straight series of folia which are rather irregular in size, shape and lateral extent. The caudal group presents the formation of a roset. The lateral folial extensions are separated from the vermal portions by a distinct paramedian groove except the most caudal folia, in which the vermal and lateral portions are continuous. The lateral chain consists of a few simple folia immediately caudal to the fissura primarius, extending outward to the periphery as a lobulus simplex. Following these folia, there ensues a well defined lobulus ansiformis, with a rather broad poorly differentiated group of folia passing over into a definite crus 1 which turns on itself in the usual manner and returns as crus 2, with a definite intercrural sulcus. At the point where crus 2 again resumes contact with the vermal group, the folia turn backward as the lobulus paramedianus which terminates in two rather broad folia that are continuous with extensions from the most caudal vermal folia of lobulus C 2. Lobulus C 1 consists of two well defined vermal folia which are continuous with a group of four folia that pass outward and become the caudal folia of the lobulus paramedianus, the more cephalic of which are connected with the submerged folium seen in the arbor in the depths of the fissure separating lobuli C 2 and C 1. The paramedian formation is bounded caudally by the fissura secunda. Lobulus B presents three simple vermal folia, the most cephalic of which are directly continuous with the end of the parafloccular formation. The paramedian formation is continuous in the depths of the fissura secunda with the lobulus parafloccularis by a group of diminishing folia which converge downward toward the root of the parafloccular formation. The paraflocculus itself is a relatively simple structure consisting of a series of folia which continue outward in the direction at right angles to the axis of the paramedian folia and then terminate as a rather rudimentary folial cluster. Lobulus A consists of a simple group of vermal folia which converge on a peduncle which is continuous outward in the general direction of the lobulus floccularis. The lobulus floccularis is extremely poorly developed, the only

indication which can be found of its existence being a single large folium which appears at the termination of the lobulus parafloccularis.

The insertion of the various lobules into the medullary substance shows that the first and second lobules are inserted together by a single peduncle. The third and fourth lobules show a similar arrangement, sharing a peduncle between them. The lobulus simplex, lobulus ansiformis and lobulus paramedianus are all inserted by means of a broad base into the medullary substance, while the parafloccular formation in its free portion appears ventral to, and somewhat in front of, the apex of the lobulus ansiformis.

PHYSICAL CHARACTERISTICS OF CASTOR CANADENSIS

The beaver is a terrestrial animal, thoroughly at home in the water, being capable of a more perfect means of progression in the water than on land. It can dive and swim as easily and gracefully as a seal. The body of the animal is fairly heavy, with a short neck and a narrow head; the eyes are situated well on the lateral aspect, the fields of vision overlapping to only a slight degree and possessing but little conjugated movement. The tongue is small, short and rounded and is not protrudable to any extent. The limbs are short and the hind feet are much larger than the fore feet, the body of the animal largely resting on the ground when it is quiet. It has a sort of lumbering walk-trot or gallop, whereas it swims with remarkable speed and agility. It presents a well marked broad flat tail, about 10 inches in length and covered with scales, which is capable of adding materially to its speed in traversing the water. The fore paws are short and broad, with a well developed thumb, and they are capable of a marked degree of unilateral independence, the paw grasping and holding objects such as saplings as the beaver bites the stem.

RATTUS NORVEGICUS ALBINUS (WHITE RAT)

The outline of the arbor vitae of the white rat presents a rather conical form, lobulus 4 forming the summit. The fissura primaria is situated a little cephalad to the middle of the arbor vitae, almost directly opposite the ventricular fastigium which reaches the medullary substance and is relatively wide. The arbor vitae is divided by the fissura primaria and the ventricular fastigium into anterior and posterior lobes, the anterior lobe being somewhat smaller than the posterior lobe. The fissura secunda separates the posterior lobe into two almost equal halves, being somewhat above the midline of the posterior lobe. It is situated in the usual position between lobuli B and C.

The medullary substance of the arbor vitae presents a condensation in the center of the cerebellum which is continued forward as a small nubbin into the anterior lobe from which the medullary branches arise. The medullary substance of the posterior lobe presents a small condensation from which arise the thick, heavy ray C and the slender rays B and A.

THE MEDULLARY RAYS

Ray 1 arises in conjunction with ray 2 from a common stem which springs forward from the medullary substance as a thin stalk. It does not belong, however, to lobulus 2, for an examination of the folial pattern shows that the two are separate and distinct in their foliation. Ray 2 consists of two simple branches, which diverge from one another. Ray 3 appears as a definite independent slender stem, arising from the dorsal aspect of the anterior medullary substance. It proceeds upward and forward in a somewhat arched manner, has no side branches

and terminates in a simple division. Ray 4 is similar in its origin and is also devoid of lateral stems until near its summit, where it gives off a few branches. Ray C is a thick, heavy stem appearing as a massive offshoot from the nubbin which forms the posterior medullary substance. It arises from the dorsal and caudal aspect of the posterior medullary substance and gives off thin and undivided caudal branches. There are no cephalic branches. Ray B arises as a simple continuation backward of the medullary substance and divides into two branches. Ray A arises as a simple stem, almost by a common origin with ray B, from the ventral surface of the posterior medullary substance.

THE LOBULES

Lobulus 1 is subdivided by a shallow sulcus which forms two rather broad folia. Lobulus 2 also presents two broad laminae corresponding with the terminal division of ray 2. Lobulus 3 is a simple, narrow lobulus possessing a

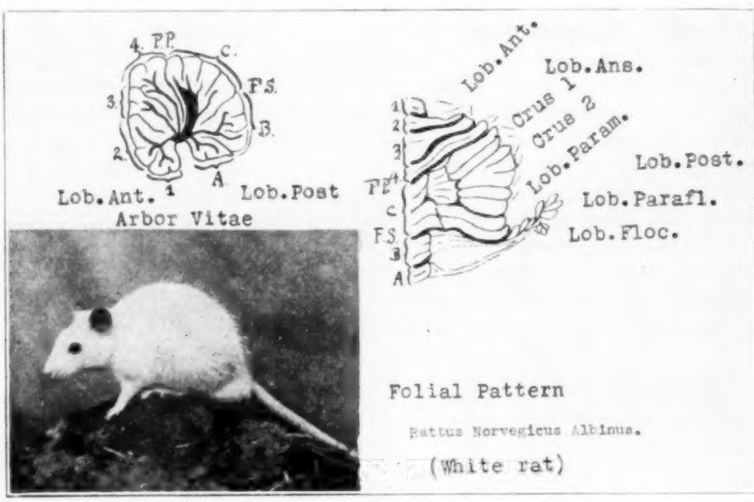

Fig. 25.—Rattus norvegicus albinus (white rat).

median division. Lobulus 4 is simply arranged, presenting only two surface folia. Lobulus C is much more extensive, although rather undifferentiated, presenting four fairly broad surface lamellae. Lobulus B presents three folia, and lobulus A, two folia.

THE FOLIAL PATTERN OF RATTUS NORVEGICUS ALBINUS

The folial pattern of the albino rat is simple and presents a division into a small anterior lobe and a considerably larger posterior lobe. The fissura primaria is somewhat cephalad of the middle of the pattern, passing almost directly outward and forward. The fissura secunda appears in its usual position between lobuli B and C and continues outward, terminating the chain of folia forming the lobulus paramedianus. Lobulus 1 presents a simple arrangement consisting of one vermal folium. Lobulus 2 presents a median subdivision but terminates as a simple folium which has a distinct extension into the hemisphere. Lobulus 3 has a similar disposition with a larger caudal division being reduced laterally

to a single folium. Lobulus 4 presents a narrow folium which is subdivided in the greater part of its extent by a sulcus, but terminates as a single folium which has, however, a considerable lateral extent. Lobulus C presents a cephalic and a caudal portion. The cephalic portion represents the usual lobulus C 2 and is confined chiefly to the vermis but is connected in its cephalic part by a thin folium with the lateral portion of the lobulus. A distinct paramedian sulcus develops, in the depths of which can be found a definite connection between the folia of the vermis and of the lateral hemispheral. The lateral folia appear as a simple chain which continues caudally as a poorly defined lobulus ansiformis with only a suggestion of crus 1 and crus 2. Succeeding crus 2 are two simple folia forming the cephalic portion of the lobulus paramedianus, caudal to which are two much wider folia which correspond to the folia usually recognized as the lateral portion of C 1 and are directly continuous with the caudal vermal folia of lobulus C 1. Lobulus B presents a cephalic folium subdivided laterally, and a caudal single folium. This forms a roset the peduncle of which is apparently continuous with the parafloccular formation. The parafloccular formation is simple in arrangement, consisting of only a few small folia, directly succeeding the folia of the paramedian formation. It continues outward into a roset. Lobulus A presents a single folium, subdivided partially by a median sulcus. Its peduncle extends toward the lobulus flocculаris which is made up of a tiny roset consisting of three small folia.

Lobulus 1 and lobulus 2 present a common peduncular implantation into the medullary substance. Lobulus 3 and lobulus 4 have independent attachments. The ansiform and paramedian formations have a common broad implantation, lateral and ventral to which is situated the parafloccular insertion.

PHYSICAL CHARACTERISTICS OF RATTUS NORVEGICUS ALBINUS

The white rat has the typical body form of a small rodent; the legs are rather slender and of moderate length. The neck is relatively short, and the head is long and pointed. The eyes are situated in the lateral position and possess but little overlapping in the visual fields. The eye movements are rather limited and do not present much conjugation. The ears are well developed. The head is freely movable. The tail is long and slender and aids the animal somewhat in its rapid movements. The activity of the animal is rather simple. It is agile and speedy, and possesses a good deal of celerity. The anterior and posterior extremities present a considerable degree of unilateral independence. The fore limbs are independent, the animal being able to sit on its haunches, hold its food in its fore paws and handle it almost as if the fore paws were hands.

CAVIA PORCELLUS (GUINEA-PIG)

The arbor vitae of the guinea-pig presents a more or less rounded outline. The fissura primaria is almost in the midline, descending perpendicularly toward the summit of the fastigium, these two structures dividing the arbor vitae into practically equivalent anterior and posterior lobes. The ventricular fastigium is prominent and wide open, and is surmounted by the medullary substance of the anterior and posterior lobes. The fissura secunda appears in its usual position between lobuli B and C, considerably above the midline of the posterior lobe, directed from before backward and upward. The medullary substance lies in the center of the cerebellum forming the roof of the ventricular fastigium, its major portion lying in the anterior lobe. There is a constriction at the point of approach of the fissura primaria to the fastigium with a downwardly curved prolongation into the posterior lobe.

THE MEDULLARY RAYS

Ray 1 is a simple ray extending forward from the downturned extremity of the anterior medullary substance. Ray 2 arises independently from the cephalic aspect of the medullary substance and divides simply. Ray 3 arises as a single ray from the dorsal and cephalic aspect of the medullary substance and divides at its summit into two simple branches. Ray 4 arises from the dorsal aspect of the anterior medullary substance and proceeds somewhat forward and upward, giving off simple branches and bifurcating at its termination. Ray C is a slender stem arising from the dorsal aspect of the caudal termination of the posterior medullary substance. It is directed upward and gives off a cephalic, a caudal and three terminal branches. The caudal branch, arising opposite the cephalic stem, forms a folium in the depths of the fissura secunda, which extends outward into the lobulus paramedianus and is ray C 1.

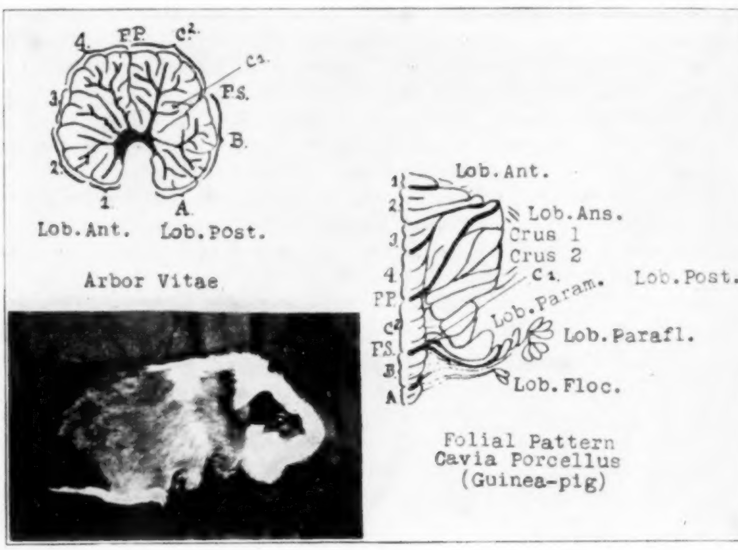

Fig. 26.—Cavia porcellus (guinea-pig).

Ray B arises as a direct continuation caudally of the posterior medullary substance. It is a single stem which undergoes a simple degree of subdivision at its termination. Ray A proceeds downward from the caudal extremity of the posterior medullary substance as a simple stem which undergoes one subdivision at its summit.

THE LOBULES

Lobulus 1 consists of a single folium. Lobulus 2 is composed of three simple folia of relatively large size. Lobulus 3 is narrow and presents a subdivision into two separate folia. Lobulus 4 is a simple conical lobulus presenting three surface folia and a few rudimentary folia in the cephalic margin of the fissura primaria. Lobulus C shows a simple process of division into four surface folia which forms lobulus C 2 and a submerged folium in the depths of the fissura secunda which is continuous with a paramedian folium and represents lobulus C 1. Lobulus B consists of two portions, a larger

dorsal and a smaller ventral division, and presents four definite folia. Lobulus A is relatively simple and consists of a single divided folium.

THE FOLIAL PATTERN OF CAVIA PORCELLUS

The folial pattern of the guinea-pig presents the usual division into anterior and posterior lobes by the fissura primaria, the former being simpler and much less extensive than the latter. The origin of the fissura primaria takes place at the middle of the folial pattern, and proceeds outward, forward and then outward again to the periphery. The fissura secunda appears in the usual position between lobuli B and C and is continued outward, caudally limiting a folium which extends from the depths of the fissura secunda outward to incorporate itself in the lobulus paramedianus. Lobulus 1 is a simple vermal folium. Lobulus 2 presents a pair of folia, the cephalic of which is subdivided in the vermal region. The lateral portion is undivided and presents distinct evidence of participating in the formation of the hemisphere. The caudal folium is undivided and extends uninterruptedly from the midline to the periphery. Lobulus 3 is confined entirely to the vermis, the limiting sulcus running forward and participating in the formation of a well defined paravermian sulcus. The lobulus ends in the depths of the fissure between lobulus 2 and lobulus 4. Lobulus 4 consists of three vermal folia which are separated from the lateral portion of the lobulus by a distinct paravermian sulcus. Lobulus 4 is continued outward into the lateral mass at a single, wide folium which assumes considerable proportions and then is reduced to a narrow lamina at the periphery. Lobulus C presents a definite division into vermal and lateral portions. The vermal portion of lobulus C 2 consists of two relatively wide folia and one narrow one, forming a roset which, by means of a peduncle, is continued outward into the hemisphere. The first folium of the lateral portion of lobulus C 2 is disposed transversely and is limited to a small triangular distribution at the cephalic extremity of the lobulus, limited by the fissura primarius in front. The next three folia are arranged as a poorly defined lobulus ansiformis forming crus 1 and crus 2. Succeeding this peculiar folial arrangement, the lobulus paramedianus appears first as two wide folia, and then two small folia which form the contracted portion of the lobulus paramedianus. The last folium but one of the lobulus paramedianus is a rather large lamina, continuous with part of the peduncle of lobulus C, while the terminal folium of the lobulus paramedianus is continuous in the depths of the fissura secunda with the submerged folium marked C 1 in the arbor vitae. Lobulus B consists of three small vermal folia, the caudal two of which show subdivision. These form a simple roset the peduncle of which is directed outward parallel with the fissura secunda, apparently ending at the base of the parafloccular formation. The lobulus paraflocculatis is a simple group of folia continuing the lateral twist of the termination of the lobulus paramedianus and being applied to the under and outer surface of the lobulus paramedianus and the ansiform formation. It terminates in a simple roset formed by three or four small folia, which is again succeeded by another roset of about the same proportions. Lobulus A consists of a single folium, subdivided in the median line, which is continued outward in the general direction of the lobulus flocculatis by means of a peduncle. The lobulus flocculatis consists of only two small folia lying in the usual position of the floccular formation, between the peduncle of the cerebellum and the lobulus paraflocculatis.

The entire anterior lobe has a common implantation in the medullary substance. The posterior lobe has an implantation for the ansiform and paramedian formation which is separate from that of the lobulus paraflocculatis.

PHYSICAL CHARACTERISTICS OF CAVIA PORCELLUS

The guinea-pig is a relatively small animal. Its head is large, with the eyes situated laterally, presenting little overlapping in the visual fields and but little mobility. The tongue is small. The neck is short. The body is round and elongated and the limbs are short. The tail is rudimentary. The guinea-pig possesses a fair degree of agility and speed. It can sit upright and use its fore limbs with a considerable degree of unilateral independence.

DASYPROCTA AGUTI (AGOUTI)

The median section of the arbor vitae of the agouti presents a more or less quadrilateral appearance, the vertical diameter somewhat in excess of the horizontal, owing to the dorsal development of lobulus 4. The fissura primaria is caudal to the middle of the arbor vitae and proceeds from behind forward and downward toward the ventricular fastigium, which appears at about the middle of the ventral aspect of the cerebellum. The fastigium is narrow and closed in. The division into two lobes by the fissura primaria and the ventricular fastigium shows that the anterior lobe predominates somewhat. The medullary substance is condensed in the center of the cerebellum, there being no clear demarcation between that belonging to the anterior lobe and that of the posterior lobe. The part which lies in the anterior lobe, according to the approximation of the fissura primaria with the fastigium, considerably exceeds that lying within the confines of the posterior lobe and is disposed as a rather bulbous protrusion into the anterior lobe, while the medullary substance of the posterior lobe appears as a rather conical protrusion into the posterior lobe.

THE MEDULLARY RAYS

Ray 1 arises as a lingular formation on the superior medullary velum. Ray 2 appears as a group of stalks arising from the extension forward of the medullary substance consisting of three small branches; the first, a single unbranched stem, the second with a terminal bifurcation, and the third arising as a single stem which by bifurcation produces two definite subsidiary branches. Ray 3 arises independently from the dorsal aspect of the anterior medullary substance and proceeds in an arched manner, upward and then forward, giving off a few lateral branches and bifurcates. Ray 4 arises directly perpendicular, opposite the ventricular fastigium, as a relatively heavy stalk, giving off small and relatively larger lateral branches. Ray C arises as a single stalk which is concerned chiefly in the foliation of lobulus C 2. It proceeds directly backward and upward, and then turns still more upward, giving off simple side branches. It presents little secondary branching. In the depths of the fissura secunda is found one submerged folium which is continuous laterally in the folial pattern with the last folium of the lobulus paramedianus and represents lobulus C 1. Ray B arises as a thick, heavy extension directly backward from the medullary substance. It gives off a few side branches and then divides into two chief subdivisions which give off lateral shoots and form terminal divisions. Ray A is a simple stalk from the ventral aspect of the medullary substance forming the caudal limit of the ventricular fastigium.

THE LOBULES

Lobulus 1 corresponds with the lingular formation, there being a small deposit of cortical substance on the superior medullary velum. Lobulus 2 is subdivided into three definite portions, the first presenting an undivided folium, the second a simple division and the third a much more definite separation into two folial

groups. Lobulus 3 is a simple lobulus with two folia; it presents a definite indentation corresponding with the position of the midbrain collicular plate. Lobulus 4 forms the summit of the anterior lobe and presents a rather extensive serial succession of simple folia on its surface. Lobulus C 2 is small and is formed by four or five simple folia. A single submerged folium in the depths of the fissura secunda which continues outward into the lobulus paramedianus represents lobulus C 1. Lobulus B shows a subdivision into two portions, a larger dorsal and a smaller ventral division, the former presenting three folia and the latter, two. Lobulus A presents a simple arrangement of consecutive folia.

THE FOLIAL PATTERN OF DASYPROCTA AGUTI

The position of the fissura primaria is somewhat caudal to the middle of the folial pattern and presents a sinuous course forward and outward to divide the

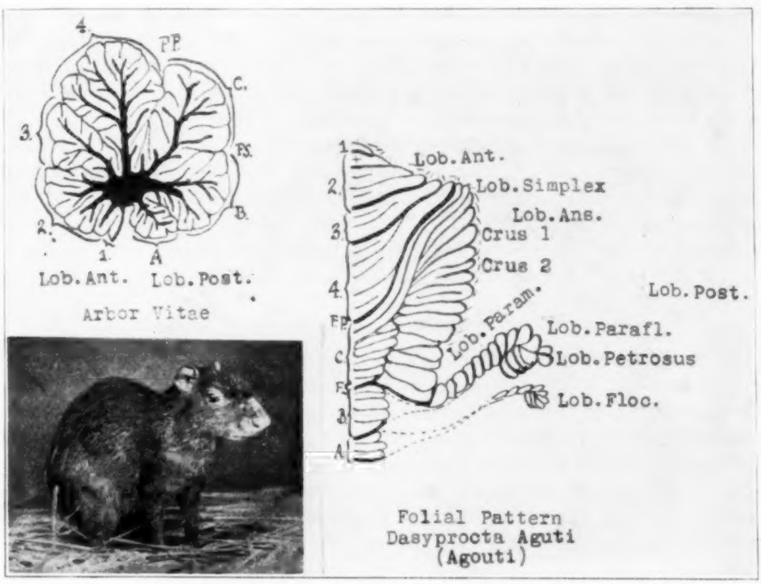

Fig. 27.—Dasyprocta aguti (agouti).

cerebellum into anterior and posterior lobes. The fissura secunda is well defined, appearing between lobuli B and C, and forms the caudal limit of the lobulus paramedianus. Lobulus 1 consists of a single vermal folium lodged on the superior medullary vellum. Lobulus 2 presents three subdivisions which are indicated in the folial pattern as the folia gradually increase in length, extending outward into the hemisphere, and also presenting vermal subdivisions. Lobulus 3 is a simple lobulus consisting of three small folia which become reduced laterally to a single folium. Lobulus 4 presents a considerable distribution in the midline, but is rapidly reduced to a single folium which extends outward into the lateral mass. It shows a definite vermal division with small, short, vermal sulci. Lobulus C 2 presents a division into two portions. The cephalic subdivision shows a pair of simple striplike folia which run directly parallel with the fissura primaria from the midline to the lateral periphery, representing a well defined lobulus simplex.

The remainder of lobulus C 2 is divided into definite vermal and lateral portions. The vermal portion consists of a series of diminishing folia. The lateral portion presents a chain of folia directly following the lobulus simplex forming a poorly defined lobulus ansiformis without any clear differentiation into crus 1 and crus 2. There is a direct continuation backward of crus 2 into the lobulus paramedianus, without any definite line of demarcation. These folia are rather broad and large, are regularly arranged and continue backward. The last folium which is a direct continuation outward of the submerged folium in the fissura secunda represents lobulus C 1. Lobulus B consists of a folial roset continued outward as a peduncle toward the base of the lobulus parafloccularis. The lobulus parafloccularis follows immediately on the terminal folium of the lobulus paramedianus; the chain of folia extends forward to the region of the poorly defined lobulus ansiformis where it terminates in a distinct roset with a protrusion outward of two folia which form a fairly well defined lobulus petrosus. This is then continued backward into a short uncus terminalis. Lobulus A consists of a few folia in the form of a roset, which is connected by a peduncle with the termination of the lobulus floccularis. The lobulus floccularis consists of a simple roset formation, with a tail formed by a few folia situated between the peduncle of the cerebellum and the parafloccular formation.

The implantation of the lobules into the medullary substance follows a relatively simple arrangement. The first lobulus and one half of the second lobulus are implanted together. The second half of the second lobulus and the third lobulus have a common peduncle. The tapering extremity of the fourth lobulus has an independent attachment, while the posterior lobe has a broad implantation lobulus C medially, and the lobulus parafloccularis laterally.

PHYSICAL CHARACTERISTICS OF DASYPROCTA AGUTI

The agouti is a rather small rodent; it has four limbs which are of fair length and quite slender, the body being raised considerably off the ground. The hind limbs are somewhat longer and more powerful than the fore limbs. The neck is well formed, and the head is small, with the eyes placed distinctly in the lateral position and possessing but little mobility. It is swift and nimble in its movements. It is a ground dwelling rodent, with hooflike claws. Its method of progression is walking and hopping, the propulsion being supplied chiefly by the longer and more powerful hind legs.

LEPUS CUNICULUS (RABBIT)

The arbor vitae of the rabbit presents a distinctly conical form. The ventral portions of the anterior and posterior lobes constitute the base, and the apex is formed by the summit of lobulus C which presents the formation termed by Bolk, the lobulus impendens. The median section is divided into about equivalent anterior and posterior lobes by the fissura primaria which extends in a curved direction backward, downward and slightly forward as it approaches the ventricular fastigium which is situated somewhat in advance of the termination of the fissura primaria and is wide open. The fissura secunda appears rather high up in the posterior lobe, dividing the lobe into almost equal halves.

The medullary substance is arranged in a rather irregular manner without any definite condensation and extending forward into lobulus 2 and upward into lobuli 4 and C.

THE MEDULLARY RAYS

Ray 1 arises as a single undivided stem from the ventral surface of the anterior medullary substance. Ray 2 appears as the direct forward prolongation of the

medullary substance, presenting a few simple branches. Ray 3 arises apparently independently from the dorsal aspect of the anterior medullary substance and gives off a number of side branches. Ray 4 continues upward and then forward, first as a fairly heavy stem, then as a slender bifurcated stalk, giving off a small number of side branches. Ray C is a long, slender stalk, arising from the insignificant posterior medullary substance; it proceeds backward, then upward and finally distinctly forward, so as partially to overhang lobulus 4. It gives off a few branches and then divides into a bifurcation which forms the summit of the lobulus. Ray B arises as a single stem from the junction of ray C and the posterior medullary substance, and then divides into two simple branches. Ray A arises as a single simple stalk from the ventral surface of the posterior medullary substance, close to the ventricular fastigium, and gives rise to a few lateral branches.

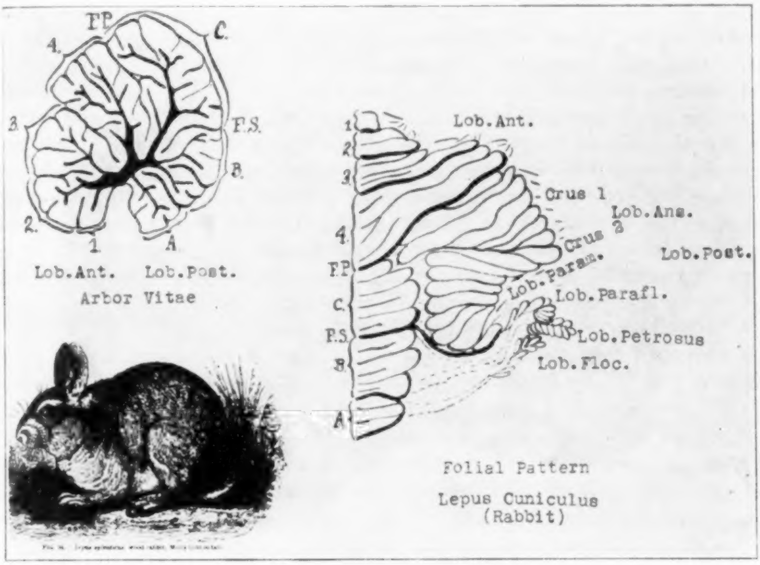

Fig. 28.—Lepus cuniculus (rabbit).

THE LOBULES

The lobulation of the arbor vitae shows a simple single folium as lobulus 1, a double folium as lobulus 2 and three folia forming lobulus 3. The impression of the mesencephalic collicular plate is clearly seen between lobuli 3 and 4. Lobulus 4 consists of two fairly large folia which are subdivided into four subsidiary lamellae. Lobulus C occupies a relatively large amount of the surface of the posterior lobe, presenting wide, simple, undivided folia. Lobulus B is divided into two portions consisting of three and two folia, respectively, while lobulus A presents two surface folia and one in the depths of the fastigium.

THE FOLIAL PATTERN OF LEPUS CUNICULUS

The folial pattern shows a distinct division into anterior and posterior lobes through the fissura primaria which appears somewhat cephalad to the middle of the pattern and proceeds outward and forward in rather a wavy course. The

anterior lobe is considerably less in extent than the posterior lobe. The fissura secunda appears in its usual position between lobuli C and B, and presents a definite continuation outward to form the caudal limit of the lobulus paramedianus. Lobulus 1 consists of a single vermal folium. Lobulus 2 presents two simple folia which are continued outward into the hemisphere. Lobulus 3 presents two folia which are subdivided by short sulci, the caudal folium being considerably more extensive than the cephalic folium. Lobulus 4 consists of two chief folia which are subdivided into five smaller folia in the vermis region but are reduced, by the failure of the sulci to continue outward into the hemisphere, to two sinuous folia which reach the periphery. The posterior lobe is divided by a definite paramedian sulcus into vermal and lateral portions. The vermal portion of lobulus C consists of four chief folia, the caudal two of which are subdivided by short sulci. These are arranged in a roset which is continuous with a wide peduncle, which, in turn, is continuous in the depths of the paramedian fissure with the ansiform and paramedian formations. There is no definite arrangement of a lobulus simplex, the folia of the lateral mass not being continuous with the vermal folia. The lateral folia are arranged in a successively diminishing series, forming a definite crus 1 which continues outward to an apex and then returns on itself by means of two or three long folia, the mesial extremities of which, in contact with the mesial extremities of the folia of crus 1, form a well defined sulcus intercruralis. Following crus 2, the paramedian formation appears as a chain of simple lamellae, which, in the region of the caudal portion of lobulus C, turns outward to be limited by the extension of the fissura secunda. Lobulus B consist of three rather large folia which are divided in the vermal region by short sulci. They converge on a peduncle which is continued outward to the beginning of the lobulus parafloccularis. The lobulus parafloccularis is a simple structure, the lamellar chain being directly continuous with the caudal folia of the lobulus paramedianus. It is continued forward and outward and terminates in a roset with a definite extension laterally, forming a lobulus petrosus and a rudimentary uncus terminalis. Lobulus A consists of a small group of folia arising from a peduncle which is continued outward in the general direction of the lobulus flocculāris. The lobulus floccularis appears as a simple roset terminating in a short chain of floccular folia situated in the usual position between the peduncle of the cerebellum and the paraflocculār formation.

The various lobules show definite medullary insertions. Lobuli 1 and 2 are implanted by means of a single peduncle. Lobuli 3 and 4 present independent peduncles, while the ansiform and paramedian formations are inserted by means of a simple, wide base into the medullary substance. The parafloccular formation is inserted ventrally and laterally to the paramedian formation.

THE PHYSICAL CHARACTERISTICS OF LEPUS CUNICULUS

The rabbit is a quick, active, four-legged animal, with a moderate sized body supported by short fore limbs and long hind limbs. The neck is short; the head is small, with large ears, and the eyes are situated in the lateral position and have but little mobility. The activity of the animal is, at times, remarkable. It is quick, lithe and energetic. The hind limbs are used chiefly in driving the animal forward in long leaps, the fore limbs being largely for the means of directing its progression. The tail is small, rudimentary and insignificant. The animal is capable of rising on its hind legs and balancing itself successfully in its effort to look around and also to search for food. In this position, with the fore limbs freed from the necessity of station in locomotion, it is capable of a considerable degree of unilateral independence, holding and turning its food in its paws as if they were hands.

MEGACHIROPTERA-PTEROPUS (FLYING FOX OR FRUIT BAT)

The arbor vitae of the fruit bat presents a more or less quadrilateral form, with a distinct prolongation of the ventrocaudal angle into a caudal extension. The fissura primaria is situated almost in a vertical line and placed directly over the ventricular fastigium, which is relatively narrow. The presence of the fissura primaria and the fastigium divides the arbor vitae into anterior and posterior lobes, the anterior being considerably smaller than the posterior lobe. The fissura secunda appears a little above the plane of the medullary substance, in the lower half of the arbor vitae, and is directed from before somewhat backward and upward. It separates lobuli B and C.

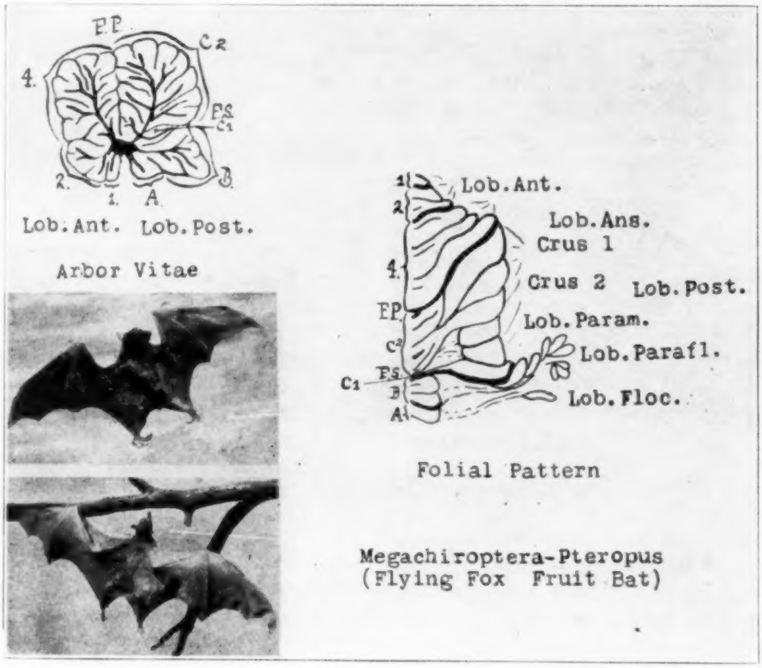

Fig. 29.—Megachiroptera-pteropus (flying fox or fruit bat).

The medullary substance is disposed as a simple condensation in the lower portion of the arbor vitae, a small more or less elongated, oval structure from which arise the medullary rays.

THE MEDULLARY RAYS

In general, the medullary rays are simple and delicate. Ray 1 arises from the ventral aspect of the anterior medullary substance as a single branch. It does not have any reduplications. Ray 2 proceeds directly forward, subdividing into two simple branches. Lobulus 4 presents a small cephalic folium at its base, and then gives off larger cephalic and smaller caudal branches. Ray C arises as a slender extension upward and backward from the medullary substance, proceeding in a curved manner backward and upward and then somewhat forward. It presents at its lower caudal extremity a single submerged branch which corresponds with

ray C 1, being continuous in the folial pattern with the caudal folium of the paramedian formation. The rest of ray C 2 undergoes rather simple division. Ray B arises as a continuation of the posterior medullary substance. It is a simple stalk, giving off a few branches. Ray A arises as a simple twig from the ventral aspect of the posterior medullary substance.

THE LOBULES

The lobules are relatively simple in arrangement. Lobulus 1 is a single undifferentiated folium. Lobulus 2 is considerably more extensive and presents three folia. Lobulus 4 presents a series of surface folia, subdivided by shallow sulci, and is relatively extensive as compared with lobulus 2. It presents a number of folia in the depths of the fissura primaria. Lobulus C 2 presents a rounded appearance, forming the major portion of the caudal vermis. It is made up of a simple series of folia which do not show any indication of a twist in the vermis pattern. It presents a folium submerged in the fissura secunda which, from its behavior in the folial pattern, shows itself to be lobulus C 1. Lobulus B presents the usual arrangement, except for the caudal prolongation of the apical folium. Lobulus A is a simple, undifferentiated folium.

THE FOLIAL PATTERN OF PTEROPUS

The folial pattern of the bat is simple and presents an equal division into anterior and posterior lobes through the presence of the fissura primaria which appears at about the midpoint of the folial pattern, proceeding outward and forward and then outward again in a rather sinuous form. The anterior lobe is considerably less in extent than the posterior lobe. The fissura secunda appears in the usual position between lobuli B and C and continues outward as the caudal limit of the paramedian formation. It bounds the folium which arises in the depth of the fissura secunda as lobulus C 1 and joins the lobulus paramedianus.

Lobulus 1 presents a single undifferentiated vermal folium. Lobulus 2 presents two simple folia which show slight lateral extensions. Lobulus 4 presents three simple folia with medial subdivisions which diminish in size as they approach the periphery. Lobulus C 2 consists of two groups of folia which show vermal characteristics. There is a paramedian sulcus which divides the first three folia from a single folium which extends outward into the hemisphere and may be the representative of the lobulus simplex. The caudal half of lobulus C is apparently connected with the ansiform formation, which is poorly developed, giving only an inkling of the formation of crus 1 and crus 2. There then succeed two rather well defined folia which form the major portion of the lobulus paramedianus. The third folium is relatively wide, and is continuous in the depths of the fissura secunda with the submerged folium which is the only representation of lobulus C 1. The free folia of the lobulus paramedianus are connected by means of a peduncle with the folia of the caudal half of lobulus C 2. Lobulus B presents two single vermal folia. It forms a simple roset which is continuous outward by means of its peduncle with the base of the lobulus parafloccularis. The lobulus parafloccularis is a simple arrangement of a few folia, terminating in a roset, and then followed again by a subsidiary small roset. Lobulus A consists of a single folium which is continuous outward by means of a peduncle with a single folium which represents what there is of the lobulus flocculari s.

Lobulus 1 and lobulus 2 share a common peduncular insertion. Lobulus 4 presents an independent peduncle. Lobulus C presents a single broad insertion with the parafloccular implantation, lateral and ventral to it.

PHYSICAL CHARACTERISTICS OF PTEROPUS

The bats represent the only order of mammals in which the fore limbs are modified for the purposes of flight, and they alone are able to sustain themselves in the air through true flight. The phalanges, except those of the thumb, are excessively lengthened to support the wing membrane. The extent of this membrane provides an instrument for propulsion and support much more efficient than the wings of the birds and enables the bat to perform aerial acrobatics of a more complicated order than those of the majority of birds. The phalanges of the thumb are short and serve for the purpose of scratching and hanging. The *Chiroptera* have an inordinately keen sense of touch and pressure which seems to be present in the nose-leaves, ears and wing membrane that apparently prevents collisions. This is of special value, since the bats are nocturnal in their activities and possess deficient eyesight. The bats habitually hang by their hind feet, although they can hang by their thumbs. They cannot walk or stand upright, and when on the ground they can only drag themselves along by their thumbs and toe-nails.

The fruit-bat, more properly termed the "flying fox" on account of the shape of its head, is much larger than the other bats, its wing spread often measuring 5 feet. There is no tail or only an extremely rudimentary one, situated ventral to, and usually independent of, the membrane between the hind legs. The fruit-bats are relatively slow and lumbering fliers, the wings moving in long slow sweeps. The head is large, with a blunt muzzle, large flabby and extensive lips and prominent movable ears. The tongue is rather large and freely movable. The eyes are situated anteriorly, with overlapping visual fields, and are conjugated in their movements. The neck is of moderate length and is freely movable. The fore limbs are modified for almost the exclusive function of flying. In hanging, the short thumbs may be used as suspending hooks. The thumbs are also used for scratching. The wings are usually folded, or they may be wrapped about the body. In fighting, the fore limbs are used as clumsy weapons, the thumb claw being of some offensive use. The body is small and without definite characteristics. The hind legs are used chiefly for grasping and hanging; when feeding, the hind legs are used to carry food to the mouth.

HAPALE JACCHUS (MARMOSET)

The arbor vitae of the marmoset presents a rather quadrilateral form, being somewhat more extensive vertically than horizontally. The division of the lobes is rendered evident by the easily identifiable character of the fissura primaria; it is almost vertical and approaches the ventricular fastigium, which is rather narrow and reaches the medullary substance. The fissura primaria and the ventricular fastigium divide the arbor vitae into practically equal anterior and posterior lobes. The fissura secunda appears in the usual position between lobuli B and C and is almost horizontal, dividing the posterior lobe into a much greater dorsal and a much smaller ventral portion. The medullary substance is simply arranged as an elongated bar without any particular predominance in either the anterior or posterior lobe except for its extension dorsally into the fourth lobule.

THE MEDULLARY RAYS

Ray 1 consists of a slender stalk arising from the ventral surface of the anterior medullary substance and bifurcating terminally. Ray 2 arises as a single stout stalk, of larger proportions than the preceding, from the cephalic extremity of the medullary substance. It immediately divides into two subdivisions which

do not present any branches but a terminal division. Ray 4 arises as a fairly heavy vertical stalk from the cephalic extremity of the medullary substance. It gives off one long branch forming lobulus 4 A which has only one small dorsal branch. The rest of the stalk then proceeds vertically and subdivides into caudal and dorsal branches. Ray C continues backward and upward from the medullary substance of the posterior lobe, giving off a vertical branch in the depths of the fissura primaria. Ray C then gives off a caudal branch to form ray C 1 and a cephalic branch which is confined to the fissura primaria. Ray C 2 continues upward as a delicate stem which terminates by dividing into three terminal bifurcated branches. Ray C 1 passes backward and upward, dividing into two terminal divisions. Ray B sweeps backward and slightly downward from the posterior medullary substance, gives off one ventral branch and subdivides.

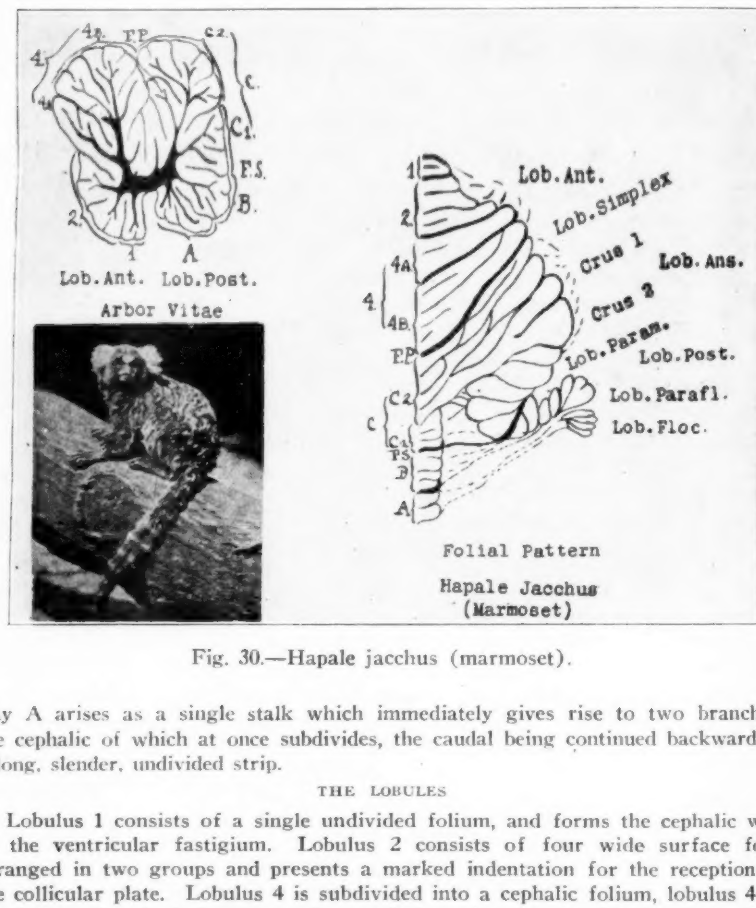

Fig. 30.—Hapale jacchus (marmoset).

Ray A arises as a single stalk which immediately gives rise to two branches, the cephalic of which at once subdivides, the caudal being continued backward as a long, slender, undivided strip.

THE LOBULES

Lobulus 1 consists of a single undivided folium, and forms the cephalic wall of the ventricular fastigium. Lobulus 2 consists of four wide surface folia arranged in two groups and presents a marked indentation for the reception of the collicular plate. Lobulus 4 is subdivided into a cephalic folium, lobulus 4 A, consisting of a single lamella, and a vertical portion forming lobulus 4 B, which consists of two groups of surface folia and a number of folia in the depths of the fissura primaria. Lobulus C subdivides into two portions, an apical portion representing lobulus C 2, consisting of a number of broad surface folia and forming the summit of the lobulus, and lobulus C 1 which consists of three

separate folia. Lobulus B is composed of three unequal surface folia. Lobulus A is simple, forming the caudal boundary of the ventricular fastigium and consisting of a few surface folia.

THE FOLIAL PATTERN OF HAPALE JACCHUS

The fissura primaria appears at about the middle of the median section and proceeds forward and outward toward the periphery, in a fairly straight course. The fissura secunda divides the posterior lobe into two portions, limiting lobuli B and C and determining the transition between the lobulus paramedianus and the lobulus parafloccularis. Lobulus 1 is a simple folium which is subdivided in the vermal region, but forms a single folium at its termination. Lobulus 2 consists of three folia which extend outward, each one progressively to a greater distance. Lobulus 4 consists of two groups: (1) lobulus 4 A, which, by its disposition, shows its resemblance to lobulus 3 of the pattern of carnivorous animals, and (2) lobulus 4 B, representing the definitive lobulus 4. Lobulus 4 A is subdivided in the vermal region but is reduced to a single folium in its lateral portion. Lobulus 4 B presents vermal divisions but survives as a single lamella at the periphery. Lobulus C is divided into two portions, a cephalic division, C 2, which presents a definite continuity between the vermal and the lateral folia, and lobulus C 1 in which this connection is interrupted. There is a definite indication of a paramedian groove. The cephalic folia of lobulus C 2 are rather irregularly arranged in the territory of the lobulus simplex. These folia are continuous caudally with an ill defined ansiform formation, there being a simple divided folium of rather large extent representing the major portion of crus 1 and crus 2. The caudal portion of lobulus C, constituting lobulus C 1, consists of vermal folia which are continued outward in the depths of the paramedian sulcus by means of a few submerged folia to the lateral chain. The rest of lobulus C 1 is continuous, by means of a peduncle, with the paramedian formation. The folia succeeding crus 1 appear as two rather broad lamellae, followed by three rather large broad folia representing the lobulus paramedianus. Lobulus B appears as two chief folia, which have partial subdivisions, forming a roset the peduncle of which is continuous with the end of the parafloccular formation. The lobulus parafloccularis appears as a direct continuation of the lamellar chain from the lobulus paramedianus, the folia turning forward and continuing to the apex of the lobulus ansiformis, where it terminates in an ill defined, rudimentary roset. Lobulus A consists of two undivided folia which are continued outward by a peduncle in the direction of the lobulus flocularis. The lobulus floccularis consists of a poorly defined roset, without any terminal group of folia. It occupies the regular position between the peduncle of the cerebelium and the parafloccular formation.

The anterior lobe presents a single peduncle which serves as an implantation for all of the folia into the medullary substance. The lateral termination of the folia of the posterior lobe present a single implantation which is situated dorsal and mesial to the origin of the folia of the lobulus parafloccularis from the medullary substance.

PHYSICAL CHARACTERISTICS OF HAPALE JACCHUS

The marmoset is a small animal from 8 to 10 inches in length. It is arboreal and quite adapted to this habitat. The head is small with the eyes situated in the anterior position and thus possessing overlapping fields of vision. The eye movements are well conjugated. The neck is short, but extremely mobile. The

limbs are all well differentiated, possessing considerable independence, the fore limbs being more independent than the hind limbs. The fore limbs are, to a considerable extent, freed from the necessities of locomotion, the animal being able to sit up and use its fore limbs as hands. The hind limbs also, to a certain extent, function as hands. The body is small. The marmoset is agile and quick in its movements.

LEMUR VARIUS (BLACK AND WHITE LEMUR)

The outline of the arbor vitae of the lemur is practically circular. The fissura primaria appears to be almost directly vertical, ending at the medullary substance directly opposite the ventricular fastigium, which is relatively wide open. These two structures, therefore, divide the arbor vitae into almost equivalent anterior and posterior lobes. The fissura secunda appears below the middle line of the posterior lobe, directed caudally and separating lobuli B and C.

The medullary substance is condensed below the middle of the arbor vitae into two portions marked by a faint constriction as the medullary substance of the anterior and posterior lobes. The anterior medullary substance is continued upward as a strong projection forming the base of ray 4.

THE MEDULLARY RAYS

Ray 1 arises as a simple undivided stalk from the ventral aspect of the anterior medullary substance. Ray 2 arises as a rather stout branch from the projection forward of the medullary substance of the anterior lobe and almost immediately divides into two independent stems, the dorsal being more branched than the ventral twig. Ray 3 arises as a fairly heavy, apparently independent shoot from the dorsal aspect of the anterior medullary substance. It projects forward in a somewhat curved fashion, giving off simple side branches, and ends in a bifurcation. Ray 4 arises as a thick, heavy stalk from the upper portion of the medullary substance. It gives rise to two secondary stems which undergo a moderately intensive secondary division.

The medullary substance of lobulus C consists of three separate groups of rays, the first arising as a simple, vertical stalk, forming a part of the caudal boundary of the fissura primaria; the second arising as a curved thick stem which extends upward as ray C 2, undergoing a fairly complicated terminal division, and the third passing almost directly caudal, as a simple stem undergoing further division. Ray B appears as a single stalk, a direct continuation caudally of the posterior medullary substance. It gives off one side branch ventrally and divides terminally. Ray A is a simple stalk without subdivision.

THE LOBULES

The first lobulus appears as a simple, undivided folium, forming the cephalic boundary of the ventricular fastigium. The second lobulus presents a series of five small folia subdivided into two groups. Lobulus 3 consists of two surface folia and is a narrow elongated lobulus. Lobulus 4 consists of two groups of three folia each. It is the largest lobulus in the arbor vitae. Lobulus C is subdivided into two surface portions, the major division being formed by lobulus C 2 and consisting of two groups of small folia, a rather large folium appearing in the depths of the fissura primaria. Lobulus C 1 consists of two simple divided folia. Lobulus B is a small lobulus with three definite folia. Lobulus A presents only two successive folia and forms a sloping caudal wall to the ventricular fastigium.

THE FOLIAL PATTERN OF THE BLACK AND WHITE LEMUR

The fissura primaria divides the folial pattern into almost equivalent anterior and posterior lobes, and proceeds outward and forward without any material deviation. The fissura secunda appears between lobuli B and C and is continued outward to demarcate the termination of the lobulus paramedianus and the beginning of the lobulus parafloccularis. Lobulus 1 consists of a single vermal folium. Lobulus 2 consists of two separate portions, the cephalic being largely vermal while the caudal shows both vermal and lateral divisions. Lobulus 3 consists of three median folia which are reduced to one rather large folium at the periphery. Lobulus 4 is divided into two groups of folia, three or four in each subdivision, which become reduced by the termination of the sulci to two rather well defined folia. Lobulus C is divided into two portions, the cephalic of which represents lobulus C 2. Lobulus C 2, in turn,

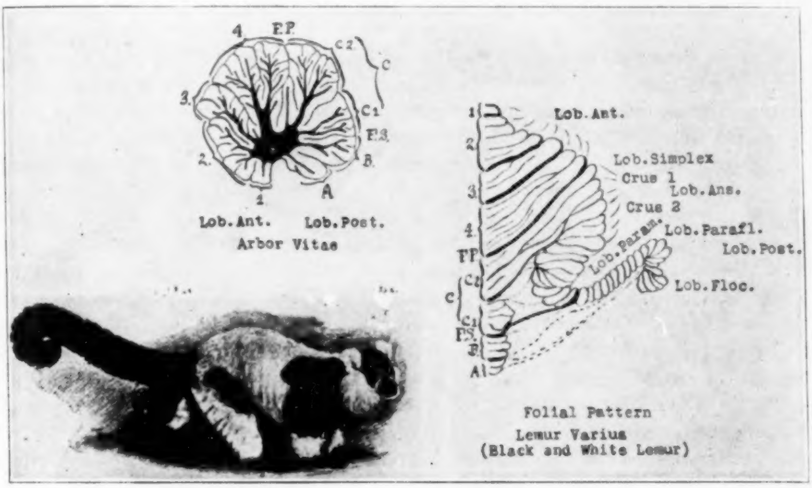

Fig. 31.—Lemur varius (black and white lemur).

is subdivided into cephalic and caudal portions. The cephalic subdivision consists of two pairs of folia continuous with the lamellae which extend throughout the hemisphere, therefore forming a fairly well defined lobulus simplex. The caudal portion represents the ansiform formation and consists of a lateral group of folia made up of a series of lamellae following directly on the lobulus simplex. The indefinite lobulus ansiformis presents a poorly defined crus 1 and crus 2 which are continuous mesially with the last folium of lobulus C 2 which scarcely shows in the pattern. Crus 2 is continuous with a series of lamellae forming the lobulus paramedianus which is interrupted by a roset. The caudal group representing lobulus C 1 consists of a vermal group of folia forming a roset, the peduncle of which is continued outward to be continuous with three or four surface folia, the lobulus paramedianus, which turns outward caudally and is separated from the beginning of the lobulus parafloccularis by the lateral continuation of the fissura secunda. Lobulus B consists of three simple folia arranged in a roset the peduncle of

which is continuous outward with the base of the parafloccular formation. The paraflocculus consists of a simple series of folia skirting the edge of the lobulus paramedianus and the lobulus ansiformis, reaching the lobulus simplex and turning on itself in the form of a roset to terminate without the development of an uncus terminalis. Lobulus A consists of two small vermal folia based on a peduncle which is continued outward in the direction of the lobulus flocculari. The lobulus floccularis consists of a simple folial roset, situated between the cerebellar peduncle and the parafloccular formation.

The lobules are implanted into the medullary substance in a rather indefinite manner. All of the folia of the anterior lobe seem to converge together in a single implantation, while a similar single implantation serves for the lobulus simplex, the lobulus ansiformis and the paramedian formation. The lobulus parafloccularis is based directly on the medullary substance, lateral and ventral to the attachment of the rest of the posterior lobe.

PHYSICAL CHARACTERISTICS OF LEMUR VARIUS

Lemur varius is nocturnal and chiefly arboreal in its habits. It is relatively small, not over 2 feet (60.9 cm.) in length. It is an excellent climber. The head is small, and the eyes are situated well forward and have overlapping fields of vision and well conjugated movements. The ears are rounded and freely movable. The neck is rather short and mobile. The tongue is long and can be extended from the mouth. The body is of moderate size. The limbs are of unequal length, the hind legs being somewhat longer. The fore limbs terminate in well formed hands with functioning thumbs which are apposable. The hind limbs also possess well formed and manually functioning extremities. There is a considerable degree of unilateral independence in both the fore and the hind limbs, that of the former being greater. The tail is of considerable length and is prehensile. The hands are well differentiated and the lemur is capable of sitting up and using its hands as explorers of the environment and to obtain and insert food into the mouth. It can also pick up objects and examine them with the hands and fingers. *Lemur varius* is a rather active animal; it possesses a considerable degree of agility and can leap from bough to bough with speed and accuracy.

MACACUS RHESUS (MACAQUE)

The arbor vitae of the macque presents a more or less rounded or oval form, the cephalocaudal diameter being somewhat greater than the vertical. The fissura primaria appears as a well defined, almost vertical sulcus, with a slight inclination downward and forward. It approaches the ventricular fastigium, producing a constriction in the medullary substance between the fissura and the fastigium. The fissura primaria and the ventricular fastigium divide the arbor vitae into about equal anterior and posterior lobes. The fissura secunda appears in the usual position between lobuli B and C and divides the posterior lobe into a smaller ventral and a larger dorsal portion. The medullary substance presents a marked constriction dividing it distinctly into the medullary substance of the anterior and posterior lobes, appearing as two rather large condensations, the mass in the anterior being considerably larger than that in the posterior lobe. The entire arbor vitae is considerably larger than that of the two preceding primates, and the lobulation is much more extensive owing to the greater arborization of the medullary substance.

THE MEDULLARY RAYS

Ray 1 appears as a simple undivided twig arising from the ventral surface of the anterior medullary substance and proceeding directly downward. Ray 2 arises as a pair of independent branches from the extension forward of the medullary substance, the first being a small stem which gives off lateral divisions, and the second a much larger stalk which proceeds directly forward giving rise to a ventral and a larger dorsal branch. Ray 4 consists of a heavy prolongation upward of the medullary substance which immediately divides into a cephalic branch that gives off side branches, and a vertical branch that continues directly upward and divides into two stalks. It presents a number of rather fine branches in the depths of the fissura primaria. Ray C arises as a direct prolongation upward and backward of the posterior medullary

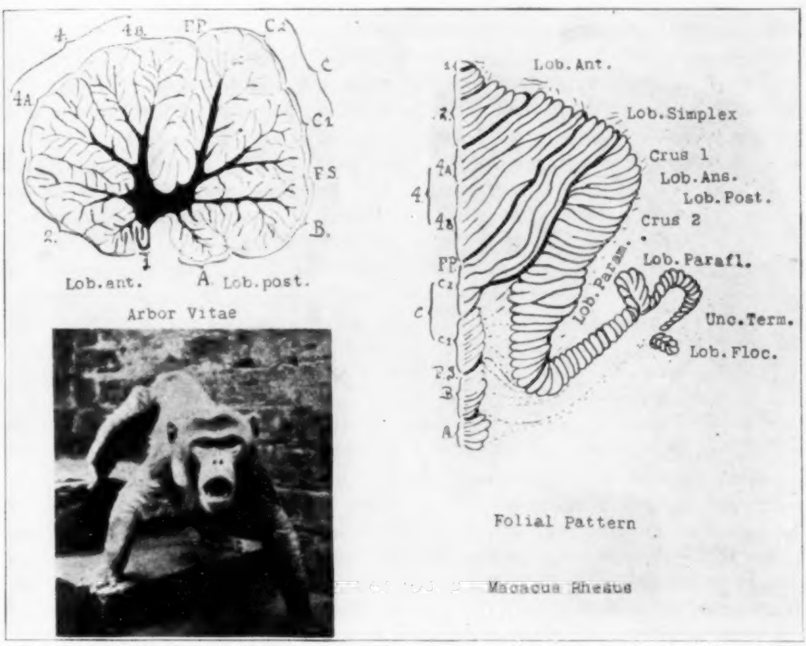

Fig. 32.—Macacus rhesus (macaque).

substance. It is a rather heavy stalk which divides into a substantial cephalic more or less perpendicular branch, giving off cephalic and caudal branches. Ray C 1 proceeds more horizontally and divides into lateral and terminal branches. Ray B arises as a stem directed backward from the mass of the medullary substance, giving off rather extensive side branches and bifurcations. Ray A springs as a thin stalk from the ventral surface of the posterior medullary substance and continues downward and backward, giving off side branches.

THE LOBULES

Lobulus 1 is a simple folium forming the cephalic margin of the ventricular fastigium. Lobulus 2 is a much more extensive lobulus subdivided into three distinct portions. Lobulus 4 is divided into two separate portions of about

equal size, both of which are further differentiated into two folial groups. It presents a considerable number of folia in the cephalic wall of the fissura primaria. Lobulus C is subdivided into two portions. Lobulus C 2 is rather small, and consists of a number of broad surface folia. Lobulus C 1 is subdivided into two smaller derivatives. Lobulus B is a rather extensive lobulus. Its terminal portion consists of a group of folia derived from the main continuation of the medullary ray and a rather extensive ventral group of folia. Lobulus A consists of a simple lobulus forming the caudal boundary of the fastigium.

THE FOLIAL PATTERN OF MACACUS RHESUS

The fissura primaria divides the folial pattern into a distinctly larger anterior lobe and a comparatively simple posterior lobe. It proceeds almost directly outward and forward, without any material curves or sinuosities. The fissura secunda appears in the usual position, separating lobuli B and C, and continues outward to limit caudally the lobulus paramedianus. Lobulus 1 consists of a single vermal folium. Lobulus 2 consists of two separate portions, the cephalic being distinctly vermal in character, while the caudal division presents a definite prolongation outward into the lateral substance, each successive folium being longer than the preceding lamella. Lobulus 4 is divided into two definite groups. The cephalic division, lobulus 4 A, presents a simple arrangement of three folia, all of which reach the periphery. Lobulus 4 B shows a definite division into vermal and lateral portions, with some irregularity in the arrangement of the folia, there being a considerable reduction in number and extent of the folia, from six in the region of the vermis to two in the periphery. Lobulus C again presents a distinct differentiation into cephalic and caudal portions, lobuli C 2 and C 1. In the former, the vermal folia are directly continuous with the simply arranged striplike folia of the lobulus simplex. There are a few caudal terminal vermal folia. Lobulus C 1 consists of vermal folia which converge on a rather broad peduncle which spreads out to become continuous with most of the ansiform formation and the lobulus paramedianus. The lobulus ansiformis presents a poorly defined crus 1 and crus 2, there being but little differentiation between this formation and the regularly arranged folial chain representing the lobulus paramedianus, which continues backward to its delimitation by the fissura secunda. Lobulus B consists of a group of vermal folia based on a peduncle which extends outward and is continuous with the base of the paraflocculi formation. The paraflocculus arises as a gradual turn from the lobulus paramedianus into a long serially arranged group of folia, constituting the lobulus parafloccularis, which continues forward to the region of the apex of the ansiform formation. A distinct roset is formed at this point, following which the chain continues forward, then turns outward and finally proceeds backward, to form an uncus terminalis. Lobulus A consists of a simple group of vermal folia with a peduncle which merges into the medullary substance. The lobulus floccularis consists of a simple folial roset and lies between the peduncle of the cerebellum and the floccular formation.

The insertion of the various lobes into the medullary substance takes place as follows: The first and the cephalic part of the second lobuli are inserted together, and the caudal part of the second with the third and fourth lobuli are inserted by means of a single peduncle. Lobulus simplex, lobulus ansiformis and lobulus paramedianus have a broad support on the medullary substance, while lateral and ventral to them is found the medullary insertion of the lobulus parafloccularis.

PHYSICAL CHARACTERISTICS OF MACACUS RHESUS

Macacus rhesus is a fairly heavily built monkey of moderate size. The head is large and massive; the eyes, situated anteriorly, possess overlapping fields of vision and are well conjugated. The jaws are heavy; the tongue is of good size and is freely movable. The neck is rather short and heavy. The body is rather slight; the upper extremities are heavy and long, and terminate in good, functional hands with rather long fingers and a short thumb which is quite apposable. The macaque can use its hands as such extensively. Its hind limbs are not so heavy and strong as the fore limbs, are shorter and are used chiefly as a means of support, although the feet are considerably more manual than are the hind limbs of *Cynocephalus.* The hind legs are used chiefly for scratching, running, jumping, etc. The macaque is at home on the ground, although he is predominantly aboreal in his activity. The macaque can be readily taught to walk upright. The tail is short and without special function. It is not prehensile.

CYNOCEPHALUS BABUIN (BABOON)

The arbor vitae of the baboon presents an outline which, while circular, is beginning to show the steady evolution of lobulus C 2 which, with the shift in the position of the medullary substance, is the major developmental process in the primate series. The fissura primaria is almost vertical in location and directly approaches the ventricular fastigium which is deep but rather wide. The arbor vitae is divided by these two structures into two almost equivalent halves, the posterior lobe being slightly greater than the anterior lobe. The medullary substance presents a marked constriction in the region of the approach of the fissura primaria to the ventricular fastigium, with a marked enlargement in the anterior lobe and a long drawn-out extension in the posterior lobe.

There is a marked increase in the branching of the medullary tree and a consequent advance in cerebellar foliation.

THE MEDULLARY RAYS

Ray 1 appears as a lingula based on the superior medullary velum. Ray 2 develops from the cephalic protrusion of the medullary substance as two independent stalks, the ventral being somewhat simpler and less extensive than the dorsal branch. There is a distinct ray 3 which arises from the dorsal aspect of the medullary substance, proceeds forward in a curved fashion and divides terminally, having given off numerous side branches. Ray 4 arises almost directly perpendicularly from the dorsal aspect of the medullary substance, and gives off side branches and a cephalic division of considerable proportion which proceeds upward, giving off lateral branches. The vertical division gives off a number of stout caudal branches which make up the folia which form the fissura primaria cephalically. Ray C 2 is drawn out caudally and upward, giving off long cephalic branches in the depths of the fissura primaria and short caudal branches. It then undergoes a rather extensive terminal arborization. Ray C 1 is given off as a moderately thick stem close to the origin of ray C which proceeds backward and upward, dividing and giving rise to numerous lateral branches. Ray B arises as a thick heavy stem close to the origin of ray C, and gives off a series of short dorsal and longer and more richly developed ventral branches. Ray A is a simple stem, close to the ventricular fastigium, which gives rise to a number of lateral branches and a terminal bifurcation.

THE LOBULES

Lobulus 1 appears as a lingula developed on the superior medullary velum and forms the cephalic wall of the ventricular fastigium. Lobulus 2 is composed of three separate folial groups, the second and third being formed by the division of the dorsal medullary ray. The first folial group is formed of two subdivided folia supported by the ventral medullary ray. The second and third groups are composed of two folia each, which are developed on the divided dorsal medullary ray. They are rather wide and relatively simple. Lobulus 3 is long and narrow, presenting a considerable degree of foliation in its contacts with lobulus 2 and lobulus 4, and divided at its summit into two folial groups. Lobulus 4 presents the usual division into a cephalic and a caudal group. The cephalic group is not given the designation of lobulus

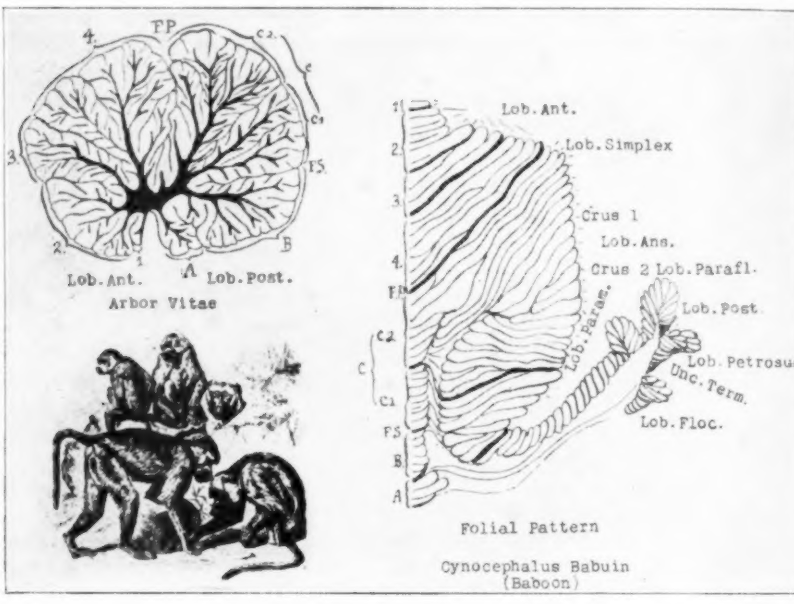

Fig. 33.—Cynocephalus babuin (baboon).

4 A on account of the relative lightness of the medullary ray. It is a conical lobulus, its base being formed by two folial groups. The remainder of lobulus 4, the usual lobulus 4 B, constitutes a moderately well developed sublobulus composed of a number of surface folia and a fairly well developed foliation in the depths of the fissura primaria. Lobulus C definitely indicates the efflorescence in lobulus C 2, which is the distinguishing feature in the progressive development of the primate cerebellum. The medullary branching is extensive, and the foliation is correspondingly increased. The spray of terminal branches is beginning to assume human proportions. Lobulus C 1 is conical, and its base occupies a considerable portion of the surface. Lobulus B is relatively quadrilateral, on account of the development of the second ventral branch, and its presents a considerable number of surface folia. Lobulus A forms the caudal wall of the ventricular fastigium and is a relatively simple lobulus.

THE FOLIAL PATTERN OF CYNOCEPHALUS BABUIN

The fissura primaria appears somewhat cephalad to the middle of the vermis, and proceeds in an almost straight line forward and outward. It divides the folial surface into a much smaller anterior and a much larger posterior lobe. The fissura secunda appears between lobuli B and C and is continued outward to limit caudally the lobulus paramedianus. The anterior lobe, with its long regular folia, is assuming definite human characteristics, while the posterior lobe is still clearly infrahuman in its organization. Lobulus 1 presents a single vermal folium. Lobulus 2 consists of three vermal folia, two of which are subdivided, and a terminal folium which presents a definite lateral extension. Lobulus 3 consists of three vermal folia, the cephalic one of which loses itself in the fissure between lobuli 2 and 3, while the remaining two continue outward as straight strips to the periphery. Lobulus 4 consists of a group of folia, the majority of which reach the periphery, only a few disappearing in adjacent fissures. Lobulus C presents two portions, a lobulus C 2 and a lobulus C 1. Lobulus C 2 presents a differentiation into cephalic and caudal divisions. The cephalic portion shows a direct continuity between the group of vermal folia and the lateral extensions which run outward parallel to the fissura primaria, representing the lobulus simplex. This portion is succeeded by a group of folia separated by a paramedian fissure into vermal lamellae and simple striplike lateral folia which are indirectly continuous with the vermal subdivisions. A group of folia then follows which represent a fairly definite lobulus ansiformis with a crus 1 and a crus 2. Crus 1 consists of a small number of folia which directly succeed the striplike folia of the more cephalic portion of the lobulus. There is no distinct apex to the ansiform formation. Crus 2 consists of a group of wide folia which gradually returns toward the midline, producing a fairly definite sulcus intercruralis, and is joined by means of a peduncle with the caudal folia of lobulus C 2. Lobulus C 1 presents a group of uniform vermal folia which is continued laterally by means of a peduncle that joins a group of rapidly diminishing folia which directly succeeds crus 2 and forms the lobulus paramedianus. The paramedian lamellar chain turns outward to its termination at the fissura secunda. Lobulus B presents a simple group of vermal folia forming a roset, the peduncle of which is directly continuous with the base of the lobulus parafloccularis. The lobulus parafloccularis presents a slow transition from the terminal folia of the lobulus paramedianus into the lobulus parafloccularis. The lobulus parafloccularis is continued forward and outward under cover of the lobulus paramedianus and the ansiform formation as a chain of lamellae which, near its cephalic extremity at the apex of the lobulus ansiformis, presents a triple roset formation, the terminal roset being a definite lobulus petrosus ending in a reduced uncus terminalis. Lobulus A consists of three vermal folia forming a roset which is based on a peduncle that fades away into the medullary substance in the direction of the lobulus floccularis. The lobulus floccularis begins in close connection with the uncus terminalis of the lobulus parafloccularis as a folial roset and then dwindles away in a diminishing series of folia.

The lobules are implanted into the medullary substance by means of a few simple peduncles. The small first lobulus presents a separate implantation. The second, third and fourth lobuli possess a common implantation. The remainder of the hemisphere is implanted in a linear fashion along the beginning of the sulcus horizontalis magnus where the cerebellum is folded on itself.

PHYSICAL CHARACTERISTICS OF CYNOCEPHALUS BABUIN

Cynocephalus babuin belongs to the dog-faced baboons. The animal is large, about the size of a large dog, but considerably more powerful and much heavier. Its head is rather massive, with a protruding snout which carries the nostrils. The eyes are situated anteriorly and possess overlapping fields of vision; they are well conjugated in their movements. The jaws are heavy, and the tongue is of moderate size and mobile. The neck is of moderate length and freely movable. The body is long and is supported by the four limbs, the hind limbs being longer than the fore limbs. The tail is short. This animal is terrestrial, frequenting both dry and stony localities. It is quite powerful, the fore limbs being especially well developed. The baboon walks on all fours, the hands being placed flat down on the ground with the head bent downward. The fore limbs are used independently to turn over sticks, stones, etc., in the search for food. Both the fore and hind limbs are unilaterally independent, the former to a much greater extent. It is a rather awkward, ungainly animal and is not possessed of any great speed.

CEBUS

The arbor vitae of the cebus presents a more or less circular form. The fissura primaria is easily identifiable as a vertical sulcus descending toward the ventricular fastigium which is relatively wide open and not deep. These two structures divide the arbor vitae into two lobes, anterior and posterior, which are about equal in extent. The fissura secunda appears between lobuli B and C, directed from before backward and upward. The medullary substance is condensed in the center, presenting approximately equal portions in the anterior and posterior lobes separated by a slight constriction. The medullary substance of the anterior lobe appears heavier on account of the heavy ray 4. The arbor vitae is not so richly developed as is that of *Cynocephalus*, but the organization of lobulus C 2 seems to indicate a further advance in the primate series over that presented by *Cynocephalus*, and more in the line with the human type. The lighter architecture of the cerebellum may be due to the much smaller corporeal bulk of the cebus as compared with that of the baboon. The cebus is definitely more bimanual than the baboon.

THE MEDULLARY RAYS

Ray 1 appears as a lingula, based on the superior medullary velum. Ray 2 arises as a direct extension forward of the anterior medullary substance, giving rise at once to two subdivisions which again subdivide, the dorsal more richly than the ventral branch. Ray 3 arises as an independent stem from the dorsal and cephalic aspect of the medullary substance. It forms a long, slender ray, gives off lateral branches and bifurcates. Ray 4 arises as a marked extension upward of the anterior medullary substance, giving rise to a cephalic branch which, if heavier, would be called ray 4 A, and then continuing upward as a vertical branch again subdivides, giving rise to lateral and terminal subdivisions as ray 4. There are a few simple branches from the caudal aspect of ray 4. Ray C arises as a direct extension upward and backward from the posterior medullary substance as a rather stout stem which divides at once into two subsidiary branches, a cephalic ray C 2 which continues upward in a curved fashion forward, giving off one cephalic branch and then smaller caudal and terminal branches. Ray C 1 proceeds more obliquely, backward and upward, giving off a greater number of ventral

branches, and subdivides into a terminal group. Ray B arises as a direct extension backward of the medullary substance, giving off lateral branches and subdividing. Ray A arises as a single stem from the ventral aspect of the medullary substance, and curves downward and backward, giving off lateral branches.

THE LOBULES

Lobulus 1 consists of three or four folia based on the superior medullary velum as a lingula. Lobulus 2 consists of two subgroups of folia, the ventral subdivision being a single group of folia, while the dorsal subdivision presents two folial groups. The surface folia are rather wide. Lobulus 3 is a long, narrow conical lobulus which presents a number of submerged folia and a basal group of two folial clusters. Lobulus 4 is a rather large conical lobulus which is subdivided into two main sublobules. The cephalic division is rather

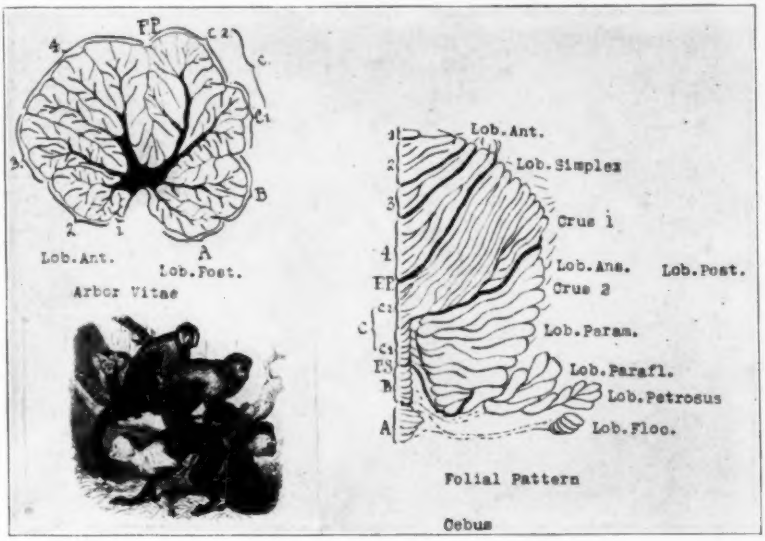

Fig. 34.—Cebus.

narrow and presents two surface folia. The caudal division is much wider, makes up the greater part of the lobulus and is divided into two surface groups of folia, there being a number of simple submerged folia in the fissura primaria. Lobulus C is relatively simple in the arbor vitae, but much more extensive in the folial pattern. It is relatively delicate in its architecture, and presents a rather large folial group in the fissura primaria and a series of surface folia. Lobulus C 1 is triangular, its ventral portion being made up of a number of folia, while its free surface is made up of two definite folial groups. Lobulus B is well developed and presents two groups of surface folia. Lobulus A is rather long drawn-out and forms a rather sloping caudal wall for the ventricular fastigium.

THE FOLIAL PATTERN OF CEBUS

The folial pattern presents a beginning expansion in the region of the lobulus ansiformis which will be found to be the predominating change in

the primate series. This rather extensive development is rather surprising in view of the simple organization of lobulus C in the arbor vitae. The fissura primaria divides the pattern into a small anterior lobe and a larger posterior lobe, arising at about the middle of the folial pattern and proceeding forward and outward. The fissura secunda appears between lobuli B and C and serves to differentiate the termination of the lobulus paramedianus from the lobulus parafloccularis. The development of the anterior lobe and the lobulus ansiformis presents a definite advance over that shown in the baboon toward the human type.

Lobulus 1 consists of a single undifferentiated surface vermal folium as the lingula. Lobulus 2 shows a distinct differentiation into the vermal and lateral portions by the direction and inclination of the sulci, which produce five folia at the median line, which are reduced to two at the periphery of the lobulus. Lobulus 3 is a narrow lobulus beginning as three folia which are reduced to two and then to one. Lobulus 4 shows a distinct differentiation into a vermal and lateral region, the sulci tending to approach each other and run into the preceding fissures, seven folia being reduced to two in the lateral extremity of the lobe. Lobulus C is subdivided into a cephalic lobulus C 2 and a caudal lobulus C 1. The vermal folia of lobulus C 2 are directly continuous with long striplike lateral folia which run outward forming a well defined lobulus simplex. Many of these sulci fail to reach the periphery. Following the folia of the fairly well defined lobulus simplex, there ensues a gradually diminishing series of folia which forms a rather undifferentiated crus 1, which turns on itself and, with a rather long folium, forms an indefinite crus 2. A large number of the caudal folia arise from the fissure separating lobuli C 2 and C 1. Lobulus C 1 presents a definite separation between the vermal and the lateral folia. The vermal folia consist of six small surface folia drawn together into a peduncle which spreads out to become continuous in the depths with the folia forming crus 2 and an irregular series of wide folia, the lobulus paramedianus. These folia rapidly are reduced in width and terminate in a curved series of folia which is limited by the lateral extension of the fissura secunda. Lobulus B consists of a vermal series forming a roset, the peduncle of which continues outward around the base of the lobulus paramedianus into the beginning of the lobulus parafloccularis. The lobulus parafloccularis consists of a loosely arranged group of folia representing a poorly defined roset which is applied along the lateral surface and undersurface of the lobulus paramedianus. It is continued still further forward and then outward into a well defined roset which forms a lobulus petrosus. Lobulus A consists of a group of vermal folia in the form of a roset, the peduncle of which merges into the medullary substance in the general direction of the lobulus flocculi. The lobulus flocculi consists of a simple series of folia, without any distinct roset formation.

The entire anterior lobe presents one medullary implantation, while the cephalic portion of the posterior lobe has a similar broad base, with the paramedian and parafloccular formations ventral and lateral to it.

PHYSICAL CHARACTERISTICS OF CEBUS

Cebus represents the well known specimen of monkey customarily seen with organ grinders. It is of moderate size, with fairly long extremities and a relatively small body. The head is of fair size, the ears are small and the eyes are placed well forward in the anterior position. The eyes possess overlapping fields of vision and are well conjugated in their movements. The

neck is of moderate length and is freely movable. The limbs are rather long and slender. All four extremities are used in progression. This monkey places the palms of the hands on the ground in walking, unlike the old world monkeys. Both the hands and the feet possess manual characteristics and are bilaterally independent, the fore limbs being more independent of one another than the hind limbs. The thumbs are not apposable, rising at a considerable distance above the fingers and being short and used as fingers. The tail is usually long, is actively prehensile and acts as a fifth extremity in climbing, maintaining position and other functions. This monkey is agile and quick in its movements. The fore limbs are extremely well coordinated, since cebus is able to catch flies and other insects with its hands. It is arboreal in its habitat, being perfectly at home in the trees, swinging, climbing and running along the limbs and jumping from one branch to another.

ATELES ATER (SPIDER MONKEY)

The arbor vitae of the spider monkey presents a more or less rounded outline. The fissura primaria appears somewhat in front of the middle of the arbor vitae and is directed from above downward and forward toward the ventricular fastigium which is rather deep and moderately wide. The arbor vitae is, therefore, subdivided into a smaller anterior and a larger posterior lobe. The fissura secunda occupies its usual position between lobuli B and C and is directed horizontally. The medullary substance appears as a heavy mass in the center of the cerebellum, with a slight constriction between the fissura primaria and the ventricular fastigium. It presents an enlargement as it passes into the anterior lobe, but is rather reduced in the posterior lobe. The arborization is considerably increased over that found in Cebus, and the foliation is correspondingly more complicated. The medullary rays of the posterior lobe are rather heavy.

THE MEDULLARY RAYS

Ray 1 appears as a long slender filament from the ventral aspect of the anterior medullary substance. It presents a terminal bifurcation. Ray 2 arises as two definite independent branches from the protrusion forward of the anterior medullary substance. The first is directed downward and forward, and the second upward and forward, each one subdividing—the dorsal stem somewhat more extensively—into lateral and terminal branches. Ray 4 is a heavy projection upward of the medullary substance which gives rise to a number of slender lateral branches both cephalically and caudally, while at its summit a number of fine twigs arise. Ray C 2 and Ray C 1 arise by means of a common trunk from the dorsocaudal angle of the medullary substance; the ascending branch ray C 2 passes backward and upward, giving rise to cephalic branches and a stout caudal branch which plays an important rôle in the expansion of lobulus C 2 in the hemisphere. The horizontal branch continues backward, giving off lateral branches as ray C 1, and subdivides. Ray B arises from the ventrocaudal angle of the medullary substance as a relatively long heavy stem, giving off lateral branches and subdividing terminally. Ray A arises from the ventral aspect of the medullary substance, proceeds downward and then curves backward, giving off lateral branches.

THE LOBULES

Lobulus 1 appears as a long, narrow folium, presenting on its free surface a subdivision into two folia. It forms the cephalic margin of the ventricular

fastigium. Lobulus 2 is extensive, and is composed of two subdivisions. The first comprises a rather conical group of folia which appear on the surface as two rather wide folia. The second or dorsal division appears as two definite folial groups which result from the division of the medullary ray. The lobulus is triangular in shape, and presents a number of folia in the fissures between lobulus 2 and lobuli 1 and 4. Lobulus 4 is still larger, triangular in shape and made up of a considerable series of narrow folia in the depths of the fissures limiting the lobulus. Its surface expression is composed of two rather poorly defined folial groups. Lobulus C comprises about two thirds of the posterior lobe and is divided into a prominent lobulus C 2 and an inconspicuous lobulus C 1. Lobulus C 2 is triangular and presents on the surface a fairly simple group of folia. It presents, however, a prominent

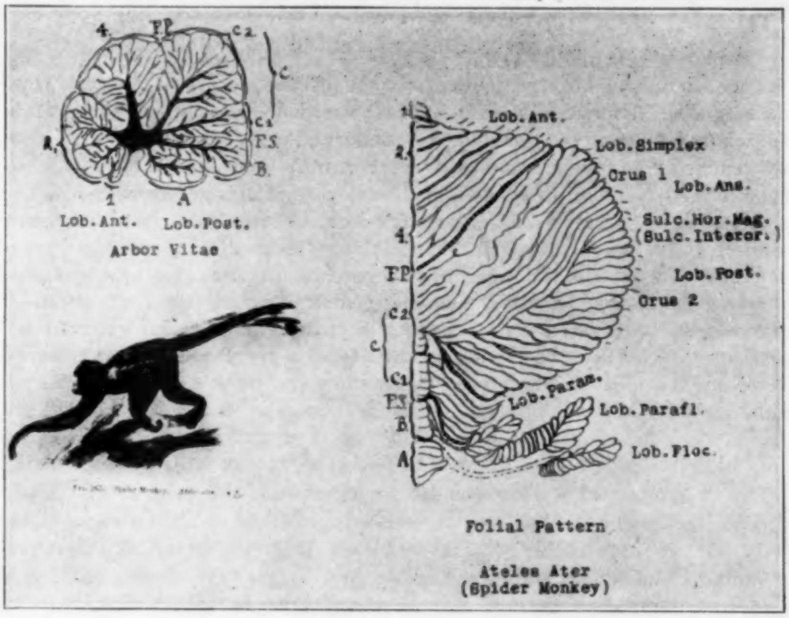

Fig. 35.—Ateles ater (spider monkey).

subdivision in its caudal portion which has a relatively heavy medullary stalk and apparently expands in the fissure between lobulus C 2 and lobulus C 1 into a considerable overgrowth which represents the major caudal portion of the lobulus ansiformis anticipating the human type, in which a small arbor folial group gives rise to an extensive hemispheral expansion. Lobulus C 1 is narrow, with a number of lateral folia presenting two folial subgroups. Lobulus B is similar and long and narrow, with two groups of surface folia. Lobulus A is a curved group of lamellae which form the caudal wall of the ventricular fastigium; it is continued caudally under the cover of lobulus B.

THE FOLIAL PATTERN OF ATELES ATER

The folial pattern of the spider monkey exhibits a marked increase in the extent and organization of the lobulus ansiformis. The division into anterior and posterior lobes is produced by the fissura primaria which begins at a

point somewhat cephalad to the middle of the vermis and proceeds almost directly outward. The fissura secunda appears in the usual position between lobuli B and C, and indicates the termination of the lobulus paramedianus. Lobulus 1 consists of two vermal folia. Lobulus 2 is constituted by two folial groups, cephalic and caudal, the latter being rather more extensive than the former. Each succeeding folium exceeds the preceding, the caudal group being disposed in a more oblique direction. Lobulus 4 consists of a simple group of folia, the vermal portions of which show a distinct tendency to form a paramedian sulcus. The lateral extensions are striplike folia which proceed directly outward with an orderly disposition. Lobulus C presents a division, primarily into two portions, lobulus C 2 and lobulus C 1. Lobulus C 2 presents a further differentiation into dissimilar cephalic and caudal portions. The cephalic division presents distinct connections between the vermal and lateral portions of the folia, while the caudal section presents a distinct paramedian separation between the vermal and lateral portions of the folia. The distinction between the two parts of the folia is shown by the change in the direction of the sulci and the separation of the parts of the folia. The sulci of the cephalic division, as they proceed outward into the lateral hemisphere, become wavy, irregular and broken, forming a poorly defined lobulus simplex. There then succeeds a group of long, wavy folia which continue outward from a peduncular origin from the arbor vitae to the periphery, indicating the production of a crus 1. This group of folia is then terminated by a series of short folia which form the apex of the lobulus ansiformis, following which there is a chain of folia of intermediate length the median prolongations of which come into contact with the folia of crus 1, thus forming a distinct sulcus intercruralis. These folia continue backward, their mesial extremities showing a tendency to curl under the preceding folia and become continuous by means of a peduncle with the vermal folia of the caudal portion of lobulus C 2, which have already been mentioned in the comment on the arbor vitae. Lobulus C 1 forms a group of vermal folia which is directly continuous laterally with the folia succeeding the folia of crus 2, thus forming an irregular but well defined lobulus paramedianus, limited caudally by the fissura secunda. The lobulus ansiformis and lobulus paramedianus thus present definite anthropoid characteristics. Lobulus B presents a simple group of vermal folia which forms a peduncle continuous with the base of the lobulus parafloccularis. The lobulus parafloccularis begins at the termination of the lobulus paramedianus as a roset, which is applied to the lateral surface of the lobulus paramedianus, and then continues forward by means of a series of narrow folia to end in a recurved tip forming a definite roset without an uncus terminalis. Lobulus A presents a simple group of vermal folia which forms a peduncle proceeding outward in the general direction of the lobulus flocularis. The lobulus flocularis is a rather extensive folial roset followed by a group of diminishing folia situated between the peduncle and the lobulus parafloccularis.

The medullary implantation is carried still further toward the human type through the origin of the entire anterior lobe by a broad base from the medullary substance. The lobulus ansiformis and the lobulus paramedianus present a similar broad implantation. These two broad implantations focus a little cephalad of the apex of the ansiform formation, thus laying the basis for the formation of the sulcus horizontalis magnus, which in the human cerebellum marks the approximation of the medullary implantation for the anterior and posterior lobes, and is continued into the hemisphere as the sulcus intercruralis. The lobulus parafloccularis is based on the medullary substance, ventral and lateral to the implantation of the lobuli ansiformis and paramedianus.

PHYSICAL CHARACTERISTICS OF ATELES ATER

The spider monkey is easily recognizable from the length of its limbs, the absence of the thumb and the exceedingly prehensile tail. It presents an adaption to an arboreal environment greater than that of any other monkey with the exception of the gibbon, as shown by its extreme agility in the use of its limbs and tail in passing, climbing, catching and jumping with great rapidity among the branches of the trees. The tail has been developed to an exquisitely adapted fifth limb; there is even a saying that it can catch fish with its tail. It shows greater unilateral independence of the fore and hind limbs than any of the apes, being able to carry on independent activities with all five members. As Hutchinson says, "It will hold fruit in one hand, find more with one foot, carry food to the mouth with another hand and walk and swing from branch to branch with the tail and the other foot, all simultaneously." The fore limbs show the greatest flexibility. It is able to walk erect, and, when it is doing so, the tail aids greatly in equilibration and is often extended forward over the head as an investigator of the environment. The head is rather small; the eyes are situated anteriorly, with overlapping fields of vision, and are conjugated in their movements. The neck is short and freely movable. The body is rather thin and slight.

SIMIA SATYRUS (ORANG-UTAN)

The arbor vitae of the orang presents a distinct step forward toward the human type in three definite characteristics; the medullary substance is distinctly concentrated in the center; ray 4 is assuming an appearance similar to that of the human stalk, and the tendency already begun in *Ateles,* of the mushrooming upward and backward of lobulus C 2, is definitely advanced in *Simia.*

The arbor vitae presents a definitely conical form, the apex of the cone being formed by lobulus C 2. The fissura primaria is situated almost directly in the midline, being nearly perpendicular. Its ventral termination is situated almost directly opposite the fastigial recess which approaches, but does not quite reach, the medullary substance. The arbor vitae shows a distinct separation into an anterior and a posterior lobe, the latter being considerably larger on account of the extensive development of lobulus C 2. The fissura secunda is situated in its usual position between lobuli B and C, and is directed somewhat from before upward and backward.

The medullary substance is concentrated in the center of the cerebellum in a somewhat narrow V-shaped fashion, the limbs of the V being formed by the strong processes 4 B and C 2. The mass of the medullary substance is rather condensed and shows a constriction between the portion which lies in the anterior lobe and that lying in the posterior lobe. The character of the arborization of the medullary tree and the consequent foliation shows a considerable degree of differentiation and strongly resembles the human type.

THE MEDULLARY RAYS

Ray 1 appears as a definite lingula, a few folia being disposed on the superior medullary velum. There is no distinct medullary ray. Ray 2 arises from the cephalic extremity of the anterior medullary substance, as a moderately strong process, extending forward and downward, and dividing at once into two definite stalks which give off lateral branches and end in a terminal bifurcation. Lobulus 4 arises as a strong, stout upward extension from the dorsal aspect of the anterior medullary substance, directed upward and slightly forward, and giving off a strong process cephalically close to its

origin, which subdivides the lobulus into lobuli 4 A and 4 B. This cephalic stalk extends forward, giving off lateral branches, and ends in a terminal division. The main stem proceeds upward dividing into a strong cephalic branch which gives off numerous lateral twigs, a decided terminal bifurcation and a smaller caudal process in the fissura primaria. The caudal division of the terminal bifurcation forms the summits of lobulus 4 B. Both of these branches are extensively subdivided. Ray C 2 arises as a strong process directed somewhat obliquely upward and backward from the dorsal aspect of the posterior medullary substance. It is a heavy stalk, giving off strong cephalic branches which lie in the depths of the fissura primaria, and a series of caudal stems which expand tremendously in the hemisphere. The ray proceeds upward and gives rise to a spray of branches which forms the summit of the lobulus and is connected with an extensive expansion in the hemisphere.

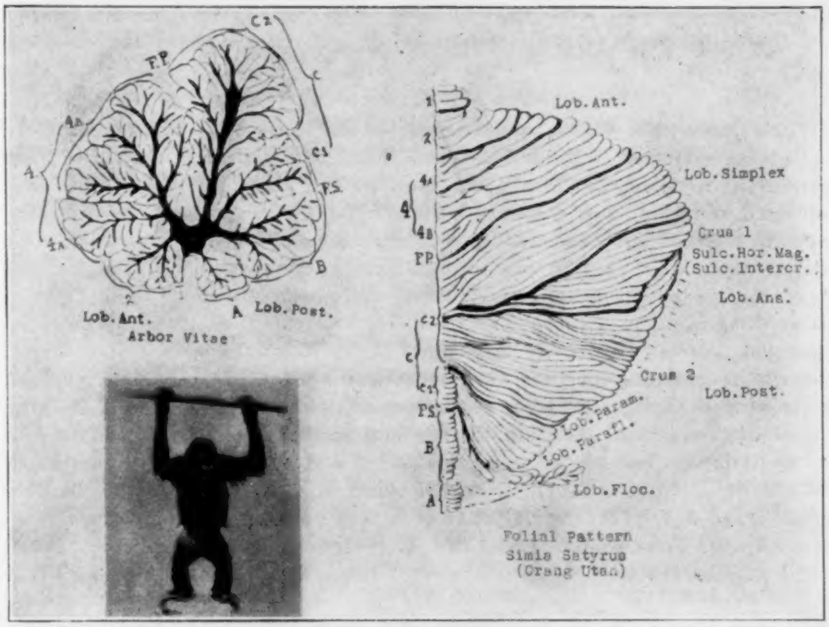

Fig. 36.—Simia satyrus (orang-utan).

Lobulus C 1 possesses an almost independent origin from the posterior medullary substance, being situated about midway between the origin of rays B and C 2. It is arched upward and backward, dividing into two definite branches both of which undergo further subdivision. Ray B arises as a relatively thick continuation backward of the posterior medullary substance, giving off side branches and then dividing into three groups of terminal branches which decrease in importance and extent from above downward. Ray A is a simple stem arising from the ventral aspect of the posterior medullary substance, proceeding downward and somewhat backward, giving off lateral branches.

THE LOBULES

Lobulus 1 is a simple lingula formation consisting of three or four folia. Lobulus 2 is a rather subordinate lobulus divided into two portions and presenting five surface folia, the dorsal being more extensive than the ventral

group. Lobulus 4 is subdivided into lobulus 4 A and lobulus 4 B, the entire complex presenting a marked similarity to the human type. Lobulus 4 A is a simple lobulus with a small number of surface folia which are subdivided into two groups. Lobulus 4 B is considerably more complicated in appearance and is subdivisible into at least three separate portions with a folial group of considerable size in the fissura primaria. Lobulus C is subdivisible into lobuli C 2 and C 1. Lobulus C 2 is a long, slender lobulus with an expanded summit, which raises itself to a considerable distance above the general outline of the arbor vitae and presents an extensive folial development in the fissures bordering the lobulus. Lobulus C 1 appears as a simple lobulus of five or six surface folia which are divided into two definite folial subgroups. Lobulus B is a relatively extensive lobulus, subdivisible into three portions, each presenting a simple serial group of folia. The upper group is a long, narrow lobulus presenting an extensive foliation, the middle group is simple and the ventral group consists of only a few folia. Lobulus A is small but rather wide, forming the caudal boundary of the fastigium.

THE FOLIAL PATTERN OF SIMIA SATYRUS

The orang-utan, in the arrangement of the cerebellar folia, presents an increasing similarity to the human cerebellum. The outline of the entire folial pattern is rounded and shows the even outline characteristic of the more advanced members of the primate order. The fissura primaria begins somewhat in front of the middle and passes outward and somewhat forward in an almost direct line. The fissura secunda appears between lobuli B and C and is continuous with a fissure which limits the caudal extremity of the lobulus paramedianus. The anterior lobe is much less extensive than the posterior lobe and presents an orderly disposition of its folia. Lobulus 1 is a lingula formation consisting of three vermal folia. Lobulus 2 presents a cephalic portion which is limited to the vermal region, while the caudal folia show an increasing tendency to extend farther and farther laterally. Lobulus 4 is subdivisible into two portions, lobuli 4 A and 4 B. Lobulus 4 A presents four folia in the midline, the cephalic two of which disappear in the fissure between lobuli 2 and 4 A. The other two are continued outward with the reappearance of one of the sunken folia. Lobulus 4 B is somewhat more complicated, showing a definite tendency to form a vermal ridge with lateral extensions. The folia in general are somewhat irregular in arrangement but extend outward throughout the width of the lobulus, the number, however, being somewhat reduced. All the folia of the anterior lobe show an increasing lateral disposition. Lobulus C presents three definite subdivisions: A cephalic portion shows a slight degree of vermal differentiation continuous with the long striplike folia which run the entire width of the lobulus; this corresponds fairly well with the disposition of the lobulus simplex. The middle group arises from a small vermal origin, the very summit of lobulus C 2 in the arbor vitae, but spreads laterally and assumes considerable proportions appearing to be crus 1 of the lobulus ansiformis. The caudal portion of lobulus C 2 presents a definite connection between the vermal and the lateral folia in its central portion, the folia of the cephalic and caudal portions tending to curl under and disappear into the sulci of the adjacent lobules and join the lower folia of the medullary ray. This part of lobulus C 2 may be homologized with crus 2 of the lobulus ansiformis. The caudal folia show a marked tendency to retract toward the midline, becoming much shorter and showing a tendency to the formation of a lobulus paramedianus. Lobulus C 1 shows a distinct differentiation between its vermal and lateral portions. The former are,

however, directly continuous with the striplike folia which run outward and arrange themselves in series with the folia of the caudal half of lobulus C 2. These folia show a progressive tendency to shorten, and the terminal folia are folded underneath the more cephalic folia as a rapidly diminishing series, forming the concluding portion of the lobulus paramedianus. Lobulus B is a relatively extensive group of folia which presents a definite rosetlike form, the peduncle of which is continuous with the rudimentary group of folia which appear in the situation of the lobulus parafloccularis. The lobulus parafloccularis begins in the recess beneath the termination of the folial chain of lobulus C 1, as a group of folia which emerge on the surface and extend outward for a short distance in a simple serial arrangement of folia, without the formation of a peripheral roset. Lobulus A presents a group of vermal folia in the formation of a roset, the peduncle of which is merged with that of the medullary substance in the general direction of the lobulus flocculāris. The lobulus flocculāris presents the appearance of a simple folial roset with a few terminal folia connected with the termination of the lobulus parafloccularis.

The insertion of the various lobules into the medullary substance does not present any definite characteristics except lobulus 1 which shows a definite peduncle. The remainder are inserted together in a continuous series throughout the entire cerebellum verging on the origin of the sulcus horizontalis magnus. A definite sulcus horizontalis magnus is discernible in the middle of the lateral extension of lobulus C 2 and it appears in the usual position of the sulcus intercruralis, crus 1 forming its cephalic lip, and the caudal margin being formed by the folia of crus 2.

PHYSICAL CHARACTERISTICS OF SIMIA SATYRUS

The orang-utan is an anthropoid ape, measuring from 3 feet 10 inches to 4 feet 6 inches in height, and is fairly heavy in its body structure. The head is large; the eyes are placed anteriorly, thus possessing overlapping fields of vision and showing conjugated movements of the eyeballs. The tongue is of moderate size and the ears are small and human in appearance. The neck is short, thick and freely movable. The arms are powerful and long, extending almost to the ankles in the erect position. The legs are short, thick and bowed. The fingers are webbed at the base, and the thumb is small. The foot is long and narrow, the great toe being short. The orang is entirely arboreal. It can progress clumsily on the ground on all fours, using its arms as crutches and resting the sides of the feet only on the ground. In the trees it travels deliberately but with perfect ease, usually swinging along under the boughs, but at times walking on them in a semi-erect position. It can stand erect and has been seen to take a step unaided. It possesses great unilateral independence of the four extremities, the skill and finesse of movement being greater in the fore than in the hind limbs. They are essentially quadrumanal in organization. The hind limbs are not organized for locomotion. They are agile and capable of a high degree of training.

GORILLA GORILLA

The pattern of the arbor vitae of the gorilla is more or less irregularly round, there being a considerable deviation from the spherical form in the extension upward and backward of lobulus C 2. The fissura primaria is situated in the usual position, almost directly vertical, with its ventral extremity approaching the summit of the fastigium. These two structures divide the arbor vitae into a smaller anterior and a larger posterior lobe. The ventricular fastigium is rather narrow and fairly deep. The fissura secunda appears in the usual position between

lobuli B and C directed from before somewhat backward and upward, dividing the lobe into a much smaller ventral and a much larger dorsal portion. The medullary substance is concentrated in the center as a large mass and is shared by both the anterior and posterior lobes without any definite demarcation. The arrangement of rays 4 and C produces a distinct U-shaped conformation in the vertical disposition of these branches as they arise from the medullary substance. The general appearance of the arbor vitae shows a distinct advance toward the human type in arborization, foliation and the special characteristics mentioned in connection with *Simia*.

THE MEDULLARY RAYS

Ray 1 presents a structure which may be viewed as a compromise between a definite stalk arising from the medullary substance and a lingula in which the definitive medullary stem is usually lacking. It arises from the ventral aspect of the anterior medullary substance and is directed downward and slightly forward, presenting a moderate degree of secondary division, and at the same time is partially merged with a layer of gray matter lying on the superior medullary velum. Ray 2 is directed forward from the medullary substance as a slender branch which gives off lateral subdivisions and terminates in a bifurcated extremity. Ray 4 is a stout branch arising from the dorsal aspect of the medullary substance, proceeding somewhat forward and upward and giving off a heavy branch cephalically which forms a definite ray 4 A. The remainder of the stalk continues upward and forward and divides into two heavy branches, which undergo secondary division, and a terminal bifurcation. Ray C arises as an upward and backward prolongation of the entire posterior medullary substance, and divides into a cephalic ray C 2 and a caudal ray C 1. Ray C 2 which proceeds obliquely upward and backward gives off a number of heavy branches in the depths of the fissura primaria and a prominent cephalic branch. It divides to form the apical sublobules of lobulus C 2. There is a single strong process forming the caudal group of folia of lobulus C 2. Ray C 1 arises near the base of ray C 2, and proceeds backward and somewhat upward, giving off a series of strong lateral branches. Ray B is a heavy ray below the center of the posterior medullary substance, proceeding backward and dividing into two groups of branches, the ventral of these again subdividing. Ray A is a heavy, thick stem from the ventral aspect of the medullary substance which proceeds downward and then almost directly backward giving off side branches of considerable size and importance.

THE LOBULES

Lobulus 1 presents characteristics which cause it to appear as a modified lingula, possessing a definite stalk, with independent branches, and also a rather broad attachment to the superior medullary velum. It is fairly extensive, consisting of three surface folia. Lobulus 2 is relatively reduced and appears as a narrow lobulus composed of lateral folia and a terminal cluster. Lobulus 4 is subdivided into a cephalic lobulus 4 A and a caudal lobulus 4 B. Lobulus 4 A is a fairly narrow lobulus proceeding straight forward and composed of lateral serial folia. The apex is somewhat widened and presents a series of single folia. Lobulus 4 B is extensive and appears like the human lobulus 4 B through the turning backward of the apical medullary ray. It is irregular in shape and is composed of two rather extensive folial groups. The cephalic group presents the usual lateral folia and a surface group which is subdivided into a smaller cephalic and a larger caudal cluster. The main caudal divisions of lobulus 4 B present a rounded summit with an extensive series of folia in the fissura primaria. Lobulus C is almost quadrilateral and is subdivided into a much larger lobulus C 2 and a small lobulus C 1. Lobulus C 2 is a considerably expanded group of folia

which shows a distinct resemblance to the human type. There is a series of relatively extensive folia in the depths of the fissura primaria. The surface folia are divided into a series of folial groups at least five in number, the cephalic group being the most conspicuous. This arrangement is similar to the type found in the cerebellum of the chimpanzee and that of the human being. The caudal group is distinct and separate. Lobulus C 1 is long and narrow, formed by lateral serial folia and presenting two small groups of surface folia. Lobulus B is extensive, beginning as a narrow structure but rather rapidly expanding into a bulbous termination formed by three folial subgroups, the dorsal and ventral divisions being rather simple and the middle one more complicated. Lobulus A appears as an elongated curved lobulus which lies under cover of lobulus B.

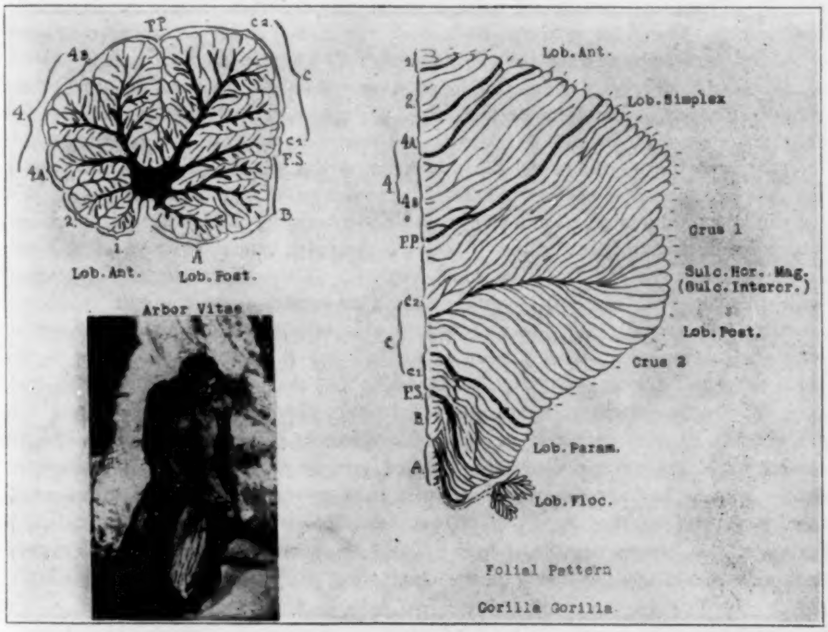

Fig. 37.—Gorilla gorilla.

THE FOLIAL PATTERN

The folial pattern also shows a distinct advance in the configuration and organization of the cerebellum as it approaches its morphologic consummation in man. The fissura primaria is situated only a little in front of the center of the folial pattern and is continued outward and forward to the periphery. The fissura secunda appears in the usual position between lobuli B and C and caudally limits a group of lateral folia which are distinctly in the paramedian position. The anterior lobe is progressively occupying less and less of the hemispheral surface. Lobulus 1 presents two vermal folia and a third which presents a definite lateral extension. Lobulus 2 is relatively reduced and presents definite vermal and lateral portions and consists of five vermal folia which are reduced to three at the periphery. Lobulus 4 is subdivided into a simple cephalic portion corresponding with lobulus 4 A and a much more extensive lobulus 4 B. Lobulus 4 A presents definite vermal and lateral portions. Lobulus 4 B is more complicated

in its arrangement, several folia appearing from the depths and maintaining themselves on the surface, while a considerable number of folia disappear by joining adjacent sulci. The lobulus does not present any definite diminution in size as it approaches the periphery. The vermal differentiation is clearly to be seen, being irregular, while the lateral striplike folia are much more regular. Lobulus C presents a cephalic portion, lobulus C 2, which is subdivisible into a number of independent portions. The most cephalic folia present a relatively simple arrangement extending from the midline to the periphery. These may be considered the folia of the lobulus simplex. The next succeeding group tends to become shorter and shorter as the folia proceed outward, forming a definite intercrural sulcus with an apex, thus comprising a fairly definite crus 1. The succeeding folia return toward the midline, and as these terminate mesially in the same sulcus they form crus 2. These two groups of folia may be considered to constitute the lobulus ansiformis. The folia continue backward, the most caudal becoming continuous with the last of the vermal folia of lobulus C 2. The intercrural sulcus presents a considerable degree of similarity in position and in character to the sulcus horizontalis magnus. The folia of lobulus C 1 present vermal portions which show definite connections through the paramedian sulcus, in the case of the cephalic folia directly with the lateral group of folia forming the lobulus paramedianus, and in the case of the caudal portion indirectly by means of a broad peduncle which joins the caudal continuation of the lateral folial chain forming the lobulus paramedianus. The lobulus paramedianus directly follows the most caudal folia of crus 2 as a series of narrowing folia. The most cephalic of these are directly continuous with the cephalic folia of lobulus C 1. The caudal folia continue to shorten laterally and mesially and are attached to a broad peduncle which is continuous with the submerged folia of lobulus C 1. Lobulus B presents a group of vermal folia provided with a definite peduncle which is continuous with the folial mass forming the caudal extremity of the folial chain of the hemisphere. These folia are not arranged so definitely in a tonsillar form as those of the chimpanzee, the caudal folia presenting a distinctly infolded arrangement, and they do not appear on the surface but are connected with the folia submerged in the fissure between lobulus B and lobulus A. The lateral folia, being connected with lobulus B, represent the lobulus parafloccularis. They do, however, present an appearance strikingly similar to the tonsil of the chimpanzee and of man. The remnants of this infolded arrangement of the terminal folia of the lobulus parafloccularis can be discerned in the caudal folia of the tonsil of man.

Lobulus A presents a group of simple vermal folia drawn into a peduncle which joins the medullary substance. The lobulus floccularis lies laterally and consists of a double group of folial rosets situated between the cerebellar peduncle and the lateral surface of the lobulus paramedianus.

The implantation of the lateral portions of the hemisphere into the medullary substance presents a simple row of direct folial implantations into the medullary substance without the interposition of definite peduncles. These form the groups of folia that make up the superior and inferior margins of the hilum of the cerebellum and are continuous outward into the bottom of the sulcus horizontalis magnus, which, in the gorilla, seems to be directly homologous with the sulcus intercruralis.

PHYSICAL CHARACTERISTICS OF GORILLA GORILLA

The gorilla is of great size and strength. The head is massive; the eyes are situated anteriorly, possess overlapping fields of vision and are well conjugated in their movements. The ears are human in their appearance, and are only slightly movable. The tongue is small. The neck is extremely heavy and freely movable. The tail is rudimentary. The extremities are of unequal length, the

arms being considerably longer than the legs and reaching to the midcalf. The hands are thick and clumsy, the thumb is short and freely functioning and the fingers are joined at their bases by a web. The lower extremities are relatively short and stocky, the leg being quite short. The toes are short and stumpy, and the great toe has more the appearance of a thumb. It is almost entirely terrestrial in habitat, although it can climb trees. In walking, the animal places the dorsal surface of the fingers on the ground, the body being brought forward with a swinging half-jump. The gorilla can stand and walk erect and it seems to assume this posture when on the aggressive. When captured young, it is capable of great training and can use its hands and feet in performing acts of great delicacy and dexterity. The quadrumanal type of organization has deferred the perfect specialization of the feet as the organ of locomotion, and the hand is the explorer of the environment.

ANTHROPOPITHECUS TROGLODYTES (CHIMPANZEE)

The pattern of the arbor vitae of the chimpanzee shows a marked similarity to that of the human being in the disposition of the medullary substance and the development of lobules 4 and C 2. In outline, it is more or less circular, with a rounded irregularity produced by lobules 4 and C 2. The fissura primaria is situated almost in a vertical line, somewhat cephalad of the middle, dividing the arbor vitae into a smaller cephalic and a larger caudal portion. The termination of the fissura primaria directly approaches the summit of the ventricular fastigium, which reaches the medullary substance. The fissura primaria and the ventricular fastigium together divide the arbor vitae into the anterior and posterior lobes. The fissura secunda appears somewhat below the middle of the posterior lobe, passing almost directly backward and somewhat above the general level of the medullary substance. The medullary substance is disposed as a markedly concentrated mass of white matter in the center of the arbor vitae between the termination of the fissura primaria and the ventricular fastigium. It appears as a small quadrilateral mass of medullary substance, giving origin to a number of lesser branches and two heavy dorsal prolongations, ray 4 and ray C. The arborization of the medullary tree is rich, and the resulting foliation is extensive. All the primary medullary rays are well defined, and the secondary branches are prominent. The arbor vitae is strikingly similar to the type found in human beings—more so than that shown by any of the other primates, and it could easily be mistaken for the human pattern. This similarity is particularly marked in the general appearance of the cerebellar section, in the form of the medullary substance, in the shape of the medullary rays 4 A and C 2 and in the general inclination of the medullary substance. The one striking dissimilarity is the lack of a definite lingula.

THE MEDULLARY RAYS

The suggestion of a lingula formation is incorporated with the base of the first branch from the medullary substance which, therefore, must be called ray 1. This arrangement is not so marked as it is in the gorilla. Ray 1 arises as a direct downward extension of the anterior medullary substance and curves forward, giving off lateral branches. Ray 2 arises as a direct cephalic prolongation of the medullary substance, giving off lateral branches and subdividing into two definite stems. Ray 4 arises from the dorsal and cephalic aspect of the anterior medullary substance and is a stout stem, directed upward and forward, giving off a submerged branch in the sulcus between lobuli 2 and 4. It subdivides into an extensive series of cephalic branches and a relatively rich apical spray. There are a number of caudal branches in the depths of the fissura primaria. The secondary and tertiary subdivision of the ray is rather extensive, producing a rich

foliation in the formation of lobulus 4. Ray C arises as a direct continuation of the entire posterior medullary substance in a more or less oblique fashion, from before backward and upward. The primary stalk is a thick heavy stem which gives off lateral subdivisions and then divides into two portions; a cephalic portion, ray C 2, extends upward and forward, giving rise to a number of cephalic and caudal divisions, and at its termination produces a spray of branches which form the summit of the lobulus and are similar to those of the cerebellum in human beings. There are two small branches which lie in the depths of the fissure between lobuli C 2 and C 1. Ray C 1 arises from the lower and caudal part of ray C, gives off an extensive series of lateral branches and then divides into two rather extensive rays which present a considerable degree of subdivision, the dorsal stem undergoing an extensive terminal branching. Ray B arises from

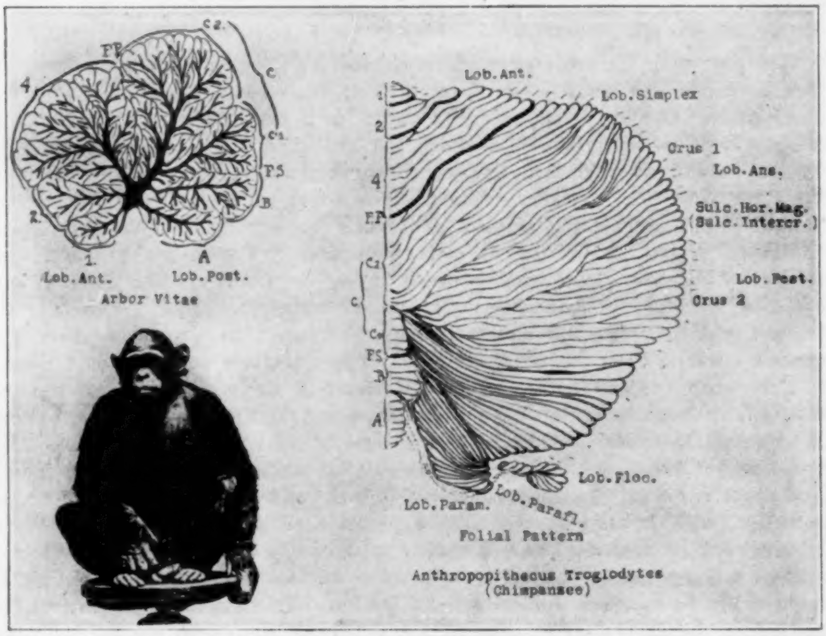

Fig. 38.—Anthropopithecus troglodytes (chimpanzee).

the caudal aspect of the posterior medullary substance, proceeds directly backward, giving off rather richly branched rays, and subdivides. Ray A is a rather heavy process from the posterior medullary substance close to the ventricular fastigium which proceeds almost directly backward, giving off lateral branches.

THE LOBULES

Lobulus 1 is fairly extensive, and would be incorporated in lobulus 2, if the abortive lingula formation had been somewhat further developed. It consists of a single folial cluster. Lobulus 2 is a narrow folial group consisting of dorsal and ventral laminae. The bifurcation of the medullary ray produces two groups of surface folia. Lobulus 4 is complicated; it is subdivided into four groups of surface folia, a submerged folial group in the fissure lying between lobuli 2 and 4 and a diminishing series of folial groups which form the cephalic margin of the fissura primaria. The four groups of surface folia are relatively simple and

form a rounded eminence extending above the general surface of the arbor vitae. Lobulus C forms by far the major portion of the posterior lobe and is subdivided into an extensive lobulus C 2 and a smaller lobulus C 1. Lobulus C 2 presents a number of folial groups which form the caudal wall of the fissura primaria. Its apex is formed by a group of surface folial clusters which extend upward above the general surface of the arbor vitae as does lobulus 4. It is strikingly similar to the human type, except that the apical folial group which in man forms the folium cacuminis is not quite so extensively developed. The same submerged folial group which in man is found to be connected with the most caudal of the folia of the lobulus tuberosemilunaris (crus 2) is also present in the depths of the fissure separating lobuli C 2 and C 1. Lobulus C 1 is fairly extensive and is divided as in man into two definite portions. Lobulus B is well developed and presents two surface folial groups which are practically identical with their homologues in the cerebellum of a human being. Lobulus A forms a well defined caudal wall of the fastigium, similar to the human type.

THE FOLIAL PATTERN OF ANTHROPOPITHECUS TROGLODYTES

The chimpanzee possesses a folial pattern which is similar to that of human beings, manifesting a considerable advance over the pattern presented by gorilla. The fissura primaria is situated well forward, separating a small anterior lobe from a voluminous posterior lobe, the major portion of which arises as the result of an extensive development in lobulus C 2. The fissura secunda appears between lobuli B and C and can be traced outward into the lamellar chain between the caudal extremity of lobulus C 1 and the lateral extension of lobulus B which is organized on the plan of the human lobulus tonsillaris. Lobulus 1 consists of a cephalic vermal folium and two caudal folia which show a slight tendency to expand laterally. Lobulus 2 is a relatively small group of folia, the cephalic lamellae being short while the terminal folium is relatively extended, showing a definite subdivision into a subdivided vermal and a single lateral portion. Lobulus 4, in contrast to its extensive development in the arbor, is rather small, presenting a definite vermal portion and a lateral division. The vermal sulci show a marked tendency to disappear in sulci which lie in front of them. The lateral folia are rather simply arranged as striplike lamellae; the cephalic laminae are somewhat irregular, but the caudal folia are long, narrow lamellae extending from the vermis to the periphery. The folia of lobulus C 2 divide themselves in general into two divisions, a cephalic which may be taken to correspond with the lobulus simplex and a caudal division consisting of rather straight folia, which show a definite differentiation from the preceding folia, with a tendency for the caudal folia to disappear under cover of the more cephalic divisions of the lobulus, with the formation of what may be considered to be a sulcus intercruralis. This sulcus shows many of the characteristics of the human sulcus horizontalis magnus. The folia succeed one another, the orderly arrangement being interrupted in several regions by the appearance from the larger sulci of numerous folia which have extended outward from the deeper lamellae of the arbor vitae and gained a place on the surface. This accounts for the greatly expanded surface area of the folia of lobulus C 2 in the hemisphere. The folia which lie cephalad to the sulcus intercruralis represent crus 1. The folia of crus 1 are short at the beginning, rapidly extend in lateral disposition and then shorten as the apex of the ansiform formation is approached. The returning series of folia representing crus 2 gradually increase and then decrease in extent as the transition into the lobulus paramedianus begins, their mesial extremities being hidden beneath the more cephalic folia as they seek the submerged lamellae of the cadual portion of lobulus C 2 in the arbor vitae. Lobulus B appears as a well defined group of

vermal folia presenting a roset formation. It is clearly defined from its lateral derivatives by a fairly deep paramedian sulcus. The peduncle of the roset rapidly expands and is continuous with an extensive group of folia which conclude the lateral chain, except for the lobulus floccularis. The folia of this expanded lateral portion of lobulus B may be homologized with the folia of the lobulus paraflocculari, although all of the characteristics of the lobulus paraflocculari of the subprimate representatives have been lost. The folial chain, as it approaches its termination, becomes rapidly reduced. Lobulus A is a relatively extensive group of vermal folia which form a roset. The ill defined peduncle loses itself in the medullary substance. The lateral portions of this lobulus, the lobulus floccularis, present a short series of folia which expand into a rather prominent roset.

The implantation of the various portions of the folia into the medullary substance is quite human in its arrangement. The implantation takes place along the lips of the sulcus horizontalis magnus as that structure arises at the hilum of the cerebellum and extends outward to become continuous with the sulcus intercruralis. The folia which reach the medullary substance along the dorsal lip of the sulcus horizontalis magnus are implanted separately, without the intervention of any peduncular formation. The folia of the caudal lip present a similar arrangement.

PHYSICAL CHARACTERISTICS OF ANTHROPOPITHECUS TROGLODYTES

The chimpanzee is a heavily built animal and is the most human of all the apes in appearance. The head is large; the eyes are situated anteriorly, thus possessing overlapping fields of vision, and are well conjugated in their movements. The ears are large, rounded and somewhat movable. The neck is short and heavy, and presents a free range of movement. The tail is rudimentary. The extremities are not so long as they are in the lower monkeys, the arms extending only to about the knee. Both the hands and the feet are rather long. The hands are well developed, the thumb being freely functioning, and the fingers are joined at their bases by a web. The toes are long, about as long as the fingers. The big toe arises at a considerable angle and resembles the thumb. The chimpanzee is able to stand and walk upright, but not so extensively as the gorilla. It prefers to proceed with the back bent forward, the body being supported by the fore limbs, with the fingers close in the palm so that the knuckles are in contact with the ground. The chimpanzee spends some of its life on the ground, but it is more arboreal than the gorilla. It is highly intelligent and imitative, and can be taught many skilled acts requiring great manual differentiation. It can use its fingers and, to a less extent, its toes, with almost human finesse and dexterity. The manual differentiation of the feet has retarded the assumption of the erect posture and postponed the division of labor, which destines the feet for locomotion and the hands and fingers for the organization of skilled movement, the characteristic of human manual development.

HOMO SAPIENS (MAN)

The form of the arbor vitae of man is more or less rounded, with a distinct surface elevation produced by lobulus C 2. The fissura primaria appears somewhat in advance of the middle of the cerebellum and proceeds downward and backward, and then directly downward, to approach the summit of the ventricular fastiguim which is rather triangular in shape. The fissura primaria and the ventricular fastigium separate the arbor vitae into a smaller anterior and a larger posterior lobe. The fissura secunda appears in its usual position between lobuli B and C. It lies almost directly horizontally and is situated a little above the

level of the medullary substance. It subdivides the posterior lobe into a larger dorsal and a smaller ventral portion.

The medullary substance appears as a more or less triangular mass of white matter, and is disposed in a peculiar oblique direction from before backward and upward. The major portion of the medullary substance is situated cephalad to the line joining the bottom of the fissura primaria and the summit of the ventricular fastigium, and therefore lies chiefly in the anterior lobe. The medullary substance of the anterior lobe forms a triangular mass from which arise the medullary rays, and from its caudal extremity the medullary substance of the posterior lobe is continued upward. The marked continuation of the medullary substance downward into the superior medullary velum and backward and upward into C 2 causes the peculiar oblique disposition of the entire medullary mass. The branching of the medullary tree is extensive, particularly in the production of the smaller stems, so that the foliation is delicate and voluminous. In man, lobulus C 2 reaches its acme of development.

THE MEDULLARY RAYS

Ray 1 appears as a definite lingula formation with the extension of the medullary substance into the superior medullary velum surmounted by a simple group of folia. Ray 2 consists of the branches which arise directly from the cephalic aspect of the anterior medullary substance. The first stalk is a relatively heavy stem which proceeds downward and forward, giving off a large number of lateral branches. The second branch is a lighter stalk, rising dorsal to the first medullary branch, which gives rise to a considerable number of lateral derivatives. There are also one or two small branches arising from the medullary substance independently. Ray 4 appears as the principal offshoot from the anterior medullary substance and arises as a thick stem from the apex of the central white matter, extending upward and somewhat forward. Ray 4 gives off close to its origin, a stout cephalic branch which subdivides the lobule into lobuli 4 A and 4 B. The rest of the stalk proceeds upward and forward, giving off several cephalic branches and a number of more slender caudal branches which lie in the depths of the fissuria primaria. It terminates by dividing into a group of rays which present a considerable degree of secondary and tertiary subdivision. Ray C arises as a direct continuation and prolongation of the posterior medullary substance in the form of a thick stem directed upward and backward which divides into a relatively heavy branch, ray C 2, and a more slender branch, ray C 1. Ray C 2 is a direct continuation upward and backward of ray C, which gives off a number of lateral subdivisions and ends in a rich terminal spray of five rays which proceed cephalically, dorsally and caudally. These undergo a considerable resubdivision and contribute the characteristic development of the human cerebellum giving attachment to the enormous mass of lateral folia which is connected with the apical folial spray. One of the caudal branches is designated as ray X. Ray C 1, the caudal division of ray C, arises as a more slender stem than ray C 2, proceeds upward and backward, giving off a considerable number of slender dorsal branches and a pair of definite ventral branches, and ends in a limited spray of secondary branches. The first considerable ventral branch is ray C 1a, while the continuation of ray C 1 becomes ray C 1b. Ray B arises as a simple stem from the caudal aspect of the posterior medullary substance, gives off a few lateral branches and divides, the derivatives giving rise to a number of smaller branches. Ray A is a rather definite stalk, arising from the medullary substance immediately above the ventricular fastigium, directed obliquely backward and downward and giving off a few subsidiary lateral branches.

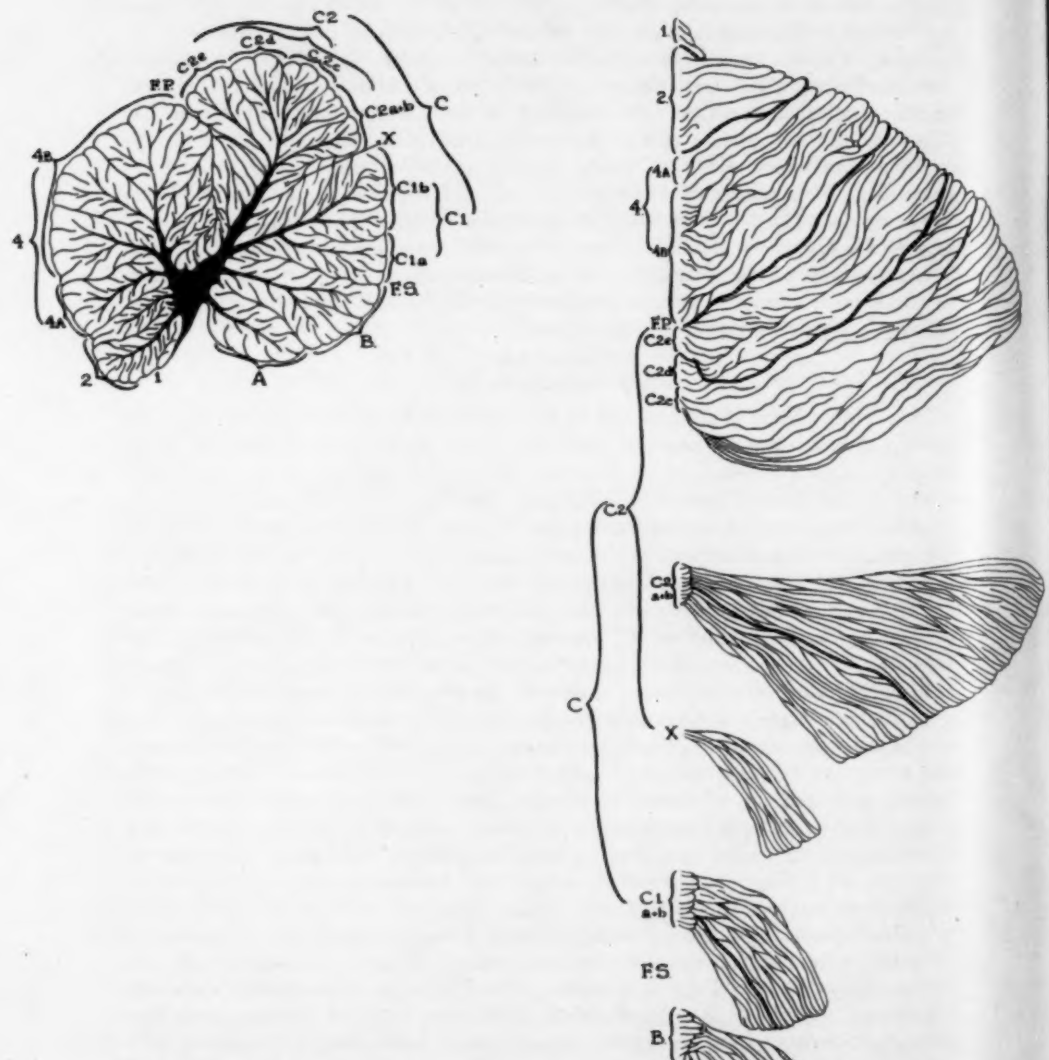

Fig. 39.—Homo sapiens (man).

THE LOBULES

Lobulus 1 consists of a few folia which are supported directly by the superior medullary velum and thus form the lingula. The group of folia which constitute lobulus 2 is subdivided into two parts, a ventral portion which is more extensive, with a closely set series of lateral folia, and a smaller dorsal collection. These two groups together compose the lobulus centralis. The remainder of the anterior lobe is made up of lobulus 4, which is called the culmen monticuli. The culmen monticuli, or lobulus 4, is roughly quadrilateral in form and is primarily subdivided into two folial groups, lobuli 4 A and 4 B. Lobulus 4 A is developed by the origin of a principal cephalic subray, ray 4 A. It is a narrow folial cluster, composed of serial lateral folia, with a surface subdivision into two smaller sublobules. Lobulus 4 B comprises the remainder of lobulus 4 and is made up of five separate sublobules. The first is rather triangular in shape, its base being located on the surface, and is subdivided into two folial groups. The remainder or deep part of the sublobulus is made up of lateral serial folia. The second sublobulus is somewhat similar in arrangement to the preceding but is less highly organized. The third sublobulus forms the summit of lobulus 4, is triangular in shape and presents three surface subdivisions. The fourth and fifth sublobules are of diminishing size and from a part of the cephalic wall of the fissura primarius. Lobulus C 2 presents a complicated subdivision and is roughly quadrilateral in outline, its dorsocaudal angle being rounded off, providing the characteristic feature of the human cerebellum. There are a number of folial groups which form the caudal wall of the fissura primaria, two of which are of greater extent than the remainder. The first group of folia of lobulus C 2 which appears on the surface forms a series of three or four folia, constituting the clivus monticuli, sublobulus C 2e. The next subdivision comprises the terminal branching of ray C 2 and appears as two groups of surface folia, sublobulus C 2d and C 2c. These together form the folium cacuminis. The concluding groups of lobulus C 2, lobuli C 2b and C 2a forming the caudal folial clusters of lobulus C 2, together constitute the tuber valvulae, although they arise as separate stems from the upper part of ray C 2. A submerged folium is designated as sublobulus X. Ray C 1, subdividing rather extensively, gives rise to at least two sublobules—lobulus C 1a and lobulus C 1b, which together form lobulus C 1, the pyramis, which is triangular in shape. Lobulus B is also triangular in form, with a deep portion made up of serial folia and a superficial division made up of two folial clusters. The combined lobulus is called the uvula. Lobulus A forms the caudal margin of the fastigium and is a simple lobulus made up of dorsal and ventral folia. It is called the nodulus.

THE FOLIAL PATTERN OF THE HUMAN CEREBELLUM

In describing and naming the lobules and fissures appearing in the folial pattern, a great deal of confusion arises on account of the folded arrangement of the cerebellum by which fissures and sulci which are really caudal in derivation become situated anatomically in front of their morphologic antecedents. With the folial pattern laid out in one plane, the terms cephalad and caudad possess their own essential significance. The folial pattern of the human cerebellum is divided by the fissura primaria into a much less extensive anterior lobe and a much larger, more complicated and highly organized posterior lobe. The fissura secunda appears between lobuli B and C and is continued outward separating the lobulus paramedianus from the lobulus parafloccularis corresponding with the lobus pyramidobiventricus and the lobulus uvulatonsillaris. Lobulus 1 corresponds with the lobulus vinculolingualis and is limited by the fissura prelingualis cephalad and the fissura precentralis (centrolingualis) caudad. It is composed of a small

number of folia supported by the superior medullary velum. Lobulus 2 presents a considerable degree of folial differentiation with a definite division into vermal and lateral portions. The lateral folia are fairly regular in this distribution, rather extensive and reach well out into the hemisphere. The number of vermal folia is considerably in excess of those which reach the periphery. Lobulus 2 corresponds with the lobulus centro-alaris bounded by the fissura precentralis (fissura centrolingualis) cephalad and the fissura prelunata (fissura culminocentralis) caudad. Lobulus 4 is subdivided into a cephalic subsidiary portion, lobulus 4 A, and a much larger caudal portion, lobulus 4 B. Lobulus 4 A presents a definite vermal differentiation with a pair of small lateral folia which run outward but do not reach the periphery. The remainder of the lobulus, lobulus 4 B, is made up of rather complicated groups of folia which run in an irregular fashion, in general, however, laterally. In several places the folia are irregular, intersecting the general lateral disposition of the lamellae. Numerous laminae appear and disappear into the sulci bounding the lobulus, and many of the sulci appear, run for short distances and disappear. The representation of this lobulus at the periphery is much less than that at the midline. Lobulus 4, the lobulus culminolunatus is composed of the culmen monticuli and the anterior lunate lobule, and is limited cephalad by the fissura prelunata (fissura culminocentralis) and caudad by the fissura superior anterior (fissura declivoculminalis).

Lobulus C is subdivided into a number of vermal and lateral portions. From before backward, the first vermal portion C 2e corresponds with the clivus monticuli and, with the lateral extensions which form the posterior lunate lobule, comprises the lobulus declivolunatus. The lobulus declivolunatus, on account of its position caudad to the fissura primaria, is homologous with the lobulus simplex. It is bounded cephalad by the fissura superior anterior (fissura declivoculminalis) and caudally by the fissura superior posterior (fissura foliodeclivalis). The lobulus is derived from a rather narrow origin from the arbor vitae and immediately extends caudally by the addition to it of folia which appear from the fissura superior posterior. The folia tend to run at first caudally and then to swing laterally, there being a tendency for the lobulus to break up into two folial groups, both of which are rather irregular. The caudal subdivision appears from the depths of the fissura superior posterior, the folia running rather irregularly toward the periphery. The two succeeding groups of vermal folia, C 2d and C 2c, are combined as the folium cacuminis. Folium C 2d is extensively represented in the vermis, but in the lateral portion of the lobulus, the folia disappear and reappear, the vermal and lateral portions apparently being connected together in the depths of the fissura superior posterior. The intermediate portion of the lobulus presents parallel sulci which, however, run obliquely across the surface of the lobule, disappearing in a secondary fissure which crosses its surface, the lobulus becoming narrower as the periphery is approached. The caudal portion of the lobulus presents a diverging series of folia which appear from under cover of the preceding folial group and continue to increase in size to the periphery, producing a distinctly triangular subdivision. These folia may be homologized with the folial arrangement of crus 1. The lateral folia tend to be arranged diagonally across the lobulus. The combined lobulus is composed of the central vermal constituent, the folium cacuminis and the hemispheral constituent, the anterior semilunar lobule, also called the posterior superior lobule. The entire lobulus is called the lobulus foliosemilunaris and is bounded cephalically by the fissura superior posterior (fissura foliodeclivalis) and caudally by the fissura horizontalis or the sulcus intercruralis.

On account of the difficulty in presenting the form of the cerebellum with the vermal folia following one right after the other in an interrupted series, the independent vermal groups and their lateral extensions are separated in the diagram.

The group of folia representing C 2a and C 2b, the lobulus tuber valvulae, is connected with an extensive series of lateral folia which present a much greater peripheral than vermal distribution, there being a distinct paramedian sulcus between the two divisions. There is a distinct vermal condensation in the number of folia. This lobulus presents a tendency for the folia to run into the fissure bounding it superiorly, therefore homologizing it with crus 2. The folia progressively diminish in lateral extent and show a tendency to be segregated into two subdivisions. This lobulus is called the lobulus tuberosemilunaris and is limited cephalad by the fissura horizontalis (fissura tuberofolialis) or the sulcus horizontalis magnus, the counterpart of the sulcus intercruralis. The lobulus is composed of the tuber valvulae and the lateral extension, the posterior semilunar lobule, which is also called the posterior inferior lobule.

The next group of folia represents a structure in the lateral hemisphere produced by the emergence of a group of submerged folia, which is marked "X" in the arbor vitae. This is an integral part of lobulus C 2a and C 2b, the folia succeeding the lobulus tuberosemilunaris as a diminishing series of folia. Lobulus C 2 is limited caudally by the fissura inferior posterior (fissura pyramidotuberalis).

Lobulus C 1 consists of a double group of vermal folia, lobuli C 1a and C 1b, and shows a definite paramedian sulcus through which the folia are continuous with a series of lateral folia which proceed outward and then caudally forming the lobulus pyramidobiventricus. By reason of its vermal associate in the arbor vitae and its form and position in the hemisphere it represents the lobus paramedianus. This lobulus is limited cephalad by the fissura inferior posterior (fissura pyramidotuberalis), and caudally by the fissura inferior anterior (fissura uvulapyramidalis).

Lobulus B represents a group of vermal folia, disposed in the form of a typical roset, drawn out into a contracted peduncle which expands markedly into a large group of folia that form the tonsil. These folia show a marked tendency toward infolding above and below, so that a narrow neck is produced which expands into a large group of folia that appear in direct continuation with the lobulus paramedianus. Under cover of its caudal portion, a number of folia run outward in a series to end in a blunt extremity completely overlain by the caudal folia of the tonsil proper. This lobulus is called the lobulus uvulatonsillaris, limited cephalically by the fissura inferior anterior (fissura uvulapyramidalis), and caudally by the fissura preuvularis (fissura nodulo-uvularis). On account of its position and particularly its connections, the lobulus uvulatonsillaris may be homologized with the lobulus paraflocculаris.

Lobulus A appears as a group of vermal folia forming a definite roset and a peduncle which appears to extend outward toward the region of the flocculus. The flocculus consists of a double roset, each part of which is terminated by a chain of folia. This is the lobulus noduloflocculаris. The lobulus noduloflocculаris is bounded cephalically by the fissura preuvularis (fissura nodulo-uvularis), and caudally by the fissura prenodularis (fissura nodiolonodularis).

PHYSICAL CHARACTERISTICS OF HOMO SAPIENS

Man presents a body adapted to an upright position. The head is rounded, the eyes are situated anteriorly, thus possessing overlapping fields of vision, and they present perfect conjugation in movement. The lips, tongue and cheeks present a marked degree of differentiation in conjunction with the larynx, respiratory muscles, etc., in the function of speech. The neck is of moderate length, and is freely movable. The trunk is of moderate size and weight. The upper and lower extremities are of about equal length. The upper extremities are completely freed from the necessities of locomotion and present the culmination in

manual dexterity. The lower extremities which are in direct line with the trunk are used chiefly for locomotion but have a marked degree of unilateral independence and are capable of a high degree of training. Man represents the final bimanual development, with a monomanual predominance, which has resulted from the specialization of the foot as the agent of support and locomotion and the freeing of the upper extremities from these necessities.

COMMENT

A definite attempt at functional localization in the cerebellum on the basis of this study is impossible. The number of forms is too small, and the distinct differences in the cerebellum are too slight to be singled out with any degree of certainty. It seems definite, however, that the size of the cerebellum and the complexity of foliation is largely dependent on the corporeal bulk of the animal. In comparing the various cerebella in regard to the degree of complexity and of functional development which they present, it seems clear that the most simply organized cerebellum which has been encountered in this series is that of *Bradypus tridactylus* in which almost the entire cerebellar development is axial, all of the folia being transversely arranged, practically equivalent in size and without any material development of the lateral outgrowths which characterize the cerebellum in the other forms. Many of the cerebella are smaller, particularly those of the rodents, the bat, the lemur and the marmoset, but in all of them there is an expansion and development, particularly in the region of lobulus C, which is only faintly suggested in the cerebellum of *Bradypus*. The reason for this is not difficult to determine and is due to the peculiar bodily conformation and physical constitution of the sloth which spends almost its entire life in a pendent position from the limb of a tree. Its means of progression are rudimentary and there is, to all intents and purposes, no unilateral independence of the fore and hind limbs. The sloth is scarcely able to drag himself along the ground and rarely leaves his characteristic suspended position.

The most complicated cerebellum is that which corresponds to the animal which possesses the greatest bulk, that is, the elephant. Closely approaching the cerebellum of the elephant in the degree of complexity comes that of the narwhal. In clearcut definition and evident convolutional organization, the primate series, and in particular *Homo sapiens,* presents interesting examples of regional development and suppression in the organization of the cerebellum.

THE PARAVERMIS

The cerebellum of the ungulates presents a typical and characteristic development. These animals require a considerable increase in cerebellar synergic activity through their greatly increased bulk, their long mobile necks and trunks and their long legs. These requirements

chiefly affect the axial musculature, and the cerebellum answers this increased demand apparently by an expansion in its median portion, the vermis. This influences the entire vermis, but particularly that part which is in connection with lobulus C and lobulus B, and results in what really amounts to a paravermis through the extreme side-to-side convolution of the vermal folial chain. This is clearly evident in the elephant, the camel, the giraffe and, to a certain extent, the calf. In these animals, the complexity of development of the median portion of the cerebellum far exceeds that of the hemisphere.

ANATOMIC HOMOLOGIES OF THE HUMAN CEREBELLUM

In regard to any effort to homologize the lobes and lobules of the human cerebellum with those of the comparative series, all investigators who have studied this question have emphasized the futility of attempting to establish a direct connection between the various lobes and lobules of the human cerebellum with the divisions and subdivision of the cerebellum as seen in the mammalian group. From the results of this study, as far as it has been carried, this is entirely true functionally, but anatomically the various lobes and lobules of the cerebellum seem to be arranged according to the same general plan as that presented by the entire comparative series from the point of view both of the arbor vitae and of the folial pattern. These homologies are apparently corroborated by the facts of embryologic development, particularly in regard to the relationship established between the vermal and hemispheral constituents of the caudal end of the folial chain, that is, the pyramis and the biventer, the uvula and the tonsil and the nodulus and the flocculus. The gradual reduction of the paraflocculus throughout the primate series is easily traceable to its remnant in *Simia, Anthropopithecus* and *Gorilla.*

THE SULCUS HORIZONTALIS MAGNUS

One of the conclusions in regard to the primate cerebellum which seems to establish itself definitely is the identification of the sulcus horizontalis magnus with the sulcus intercruralis of the lobulus ansiformis. These sulci both develop in the hemispheral expansion connected with lobulus C 2. The organization of the sulcus formed by the approproximation of the mesial extremities of the folia of crus 1 and crus 2 is easily followed in the more simple types of cerebellar crystallization and definitely establishes itself in the ungulate and carnivorous types. This ground plan is easily recognizable in the lower and intermediate primates. As the foliation of the hemispheral portions of lobulus C 2 become richer when the higher primates are reached, a gradual transition takes place into the configuration of the sulcus horizontalis magnus as seen in the gorilla and the chimpanzee. In

man, the great horizontal sulcus occupies the identical position held by the sulcus intercruralis in the lower forms, and a definite reminiscence of crus 1 and crus 2 can be made out in the arrangement of the folia forming the fissure.

LOCALIZATION IN THE ANTERIOR LOBE

According to the investigations of Bolk, André-Thomas, Durupt, Van Rijnberk and others, the various lobules of the anterior lobe have received definite synergic allocations as follows: the eye movements in lobulus 1, the lingual musculature in lobulus 2, the masticatory movements in lobulus 3 and the combination of the mimetic musculature and the activity of the laryngeal and pharyngeal muscles in lobulus 4. In a consideration of lobulus 1, the chief variation noted is in the rather extensive development of this lobule in the arbor vitae of the ungulates. This development is not carried to any extent in the hemisphere. In these animals, the eyes are placed in the lateral aspects of the head, and the direction of gaze is largely controlled by the position of the head. In the other suborders, the lobulus is fairly uniform, and a definite expansion cannot be identified in the animals in which the eyes are placed cephalically and in which the synergic control of the eyes has developed to such an extraordinary extent as that shown by the higher anthropoids and man. Lobulus 2, to which is allocated the synergic control of the lingual musculature, is highly developed in all the lower forms, such as the marsupials and the ungulates. It is fairly well developed in *Fissipedia* and considerably more highly specialized in *Pinnipedia*. It is prominent in the lower primates, then rapidly diminishes in the higher anthropoids finally to gain a considerable degree of development in man. Lobulus 3, to which is assigned the synergizing of the masticatory movements, is so variable that it is difficult to arrive at any definite conclusions in regard to its particular control. When it is present its origin and the disposition of its lateral extensions would aline it more with lobulus 4 than with lobulus 2, and when it is absent there are branches of ray 4 which suggest that it had been incorporated with lobulus 4. The only suborder in which it presents any degree of constancy is the rodents, and this would scarcely add any plausibility to the hypothetic functions assigned to it.

In regard to lobulus 4, it is difficult to believe that the synergic needs of the facial, laryngeal and pharyngeal muscles should require such an important subdivision of the cerebellum. It is only in the carnivora and the primates that the mimetic musculature has arrived at any degree of differentiation. The synergic necessities of the larynx and pharynx are only moderately advanced in the lower forms, and the human cerebellum does not show the degree of expansion which would be expected if this lobule should govern the vast range of facial expression and the

infinitely fine gradations of laryngeal tension necessitated by speech and vocal modulations. Lobulus 4 in the ungulates certainly shows a well marked development and might correspond better with the elongation and greater range of activity of the neck than the lobulus simplex, the most cephalic portion of lobulus C to which has been traditionally allocated the control of the cervical musculature.

From these fragmentary observations, it is clear that it does not seem justifiable to try to draw any definite conclusions as to functional localization in the anterior lobe. The evidence as obtained in this incomplete study does not afford any basis for corroboration or refutation of the diagrammatic localizations which are usually indicated in the various schemas of the cerebellum. It may be possible to arrive at more definite conclusions with the enlargement of the present series.

LOCALIZATION IN THE POSTERIOR LOBE

The case of the posterior lobe, however, is rather different. One of the most striking features noted in this study is the enormous expansion of the parafloccular formation in the aquatic forms. This includes not only *Cetacea* and *Sirenia* but also *Pinnipedia*. *Pinnipedia* show a perfectly definite and characteristic arbor vitae pattern which may be homologized with ease with the other carnivora. The expansion of the arbor vitae of the anterior lobe into the hemisphere follows the arrangement typical for carnivorous animals, and the ansiform formation does not present any significant variations.

Cetacea, however, show a highly distinctive evolution of the arbor vitae which offers many difficulties of analysis and defies dogmatic schematization. The folial pattern also presents many obstacles to the establishment of homologies with the other forms. This applies almost with equal force to both the anterior and the posterior lobes. The parafloccular formations, however, of all the aquatic forms disclose a surprising degree of similarity. Not only is it relatively enormous in all of these forms, occupying from two to three fifths of the entire cerebellar mass, but in its general constitution and organization it presents many striking likenesses. The aquatic forms present the highest degree of axial coordination. This is occasioned, of course, by their aquatic habitat. Their entire existence is passed in an aqueous environment, and to this they have adapted themselves by the acquisition of a type of locomotion which exhibits the most perfect segmental coordination developed by any of the mammalia and can be rivaled only by the progressive movements of the fish and the snake. In addition to this axial coordination of the muscles of the trunk, there is also an extraordinary degree of synergy between the axial musculature of the trunk and the appendicular musculature represented by the anterior flippers, the tail and the posterior extremities, largely incorporated with

the tail. These physiologic characteristics seem to be definitely associated with this enormous development of the parafloccular formation, and it would appear highly probable that this type of cerebellar organization is dependent on an aquatic habitat and the necessities imposed on the muscular organization of these forms by their environment. The marked differences in the fore limbs of the sea lion, which are capable of a considerable degree of unilateral independence, from those of the narwhal which have been reduced to mere flippers useful only in progression, is clearly paralleled by the difference in development of the lobulus ansiformis, which in the sea lion and seal is distinctly of the carnivorous type, whereas in *Cetacea* this part of the cerebellum has lost its clear definition.

It must also be borne in mind that *Pinnipedia, Sirenia* and *Cetacea* are highly specialized forms which have a phyletic ancestry quite at variance with the consummation of their adaptive radiation, and their hereditary equipment may represent rudiments either unused or usurped by functional localizations of an unusual character. This may explain the rather extensive development of lobulus 4 in manatee, an animal without a real neck, and lobulus C 2 in *Cetacea,* which have only rudimentary appendicular appendages.

The consideration of the anthropoid series presents indubitable evidence of functional localization in the posterior lobe. One of the most striking results of this study has been the gradual evolution of the form of the arbor vitae and the folial pattern throughout the primate series. Beginning with the marmoset and the lemur, which present a distinctively carnivorous type of cerebellum, the gradual development of the organization of this organ evolves in an orderly series, continuing in *Macacus* and then in *Cynocephalus babuin,* which shows distinct characteristics of the carnivora particularly of lobuli C and B, and is distinctly subordinate to the two types of *Cebidae, Cebus lunatus* and *Ateles ater,* both of which are definitely more highly specialized and developed in manual organization than is *Cynocephalus.* The arbor vitae of *Cynocephalus,* if considered independent of its lateral expansion, appears as if it should stand between *Cebidae* and *Simia satyrus.* Even a cursory glance at the folial patterns, however, clearly indicates that *Cebidae* show a more highly differentiated development in the hemispheral constituents of lobulus C, and in particular lobulus C 2. The explanation of these apparently conflicting features offers some difficulties. One, however, may theorize on this point and explain it by the assumption that *Cynocephalus* may show a divergent tendency from the general primate stem toward an increasing manual differentiation which was, however, frustrated by its increasing body bulk which forced it back from an advanced brachiation into a ground living form in which it reverted to a quadrumanal type. Whether this is actually

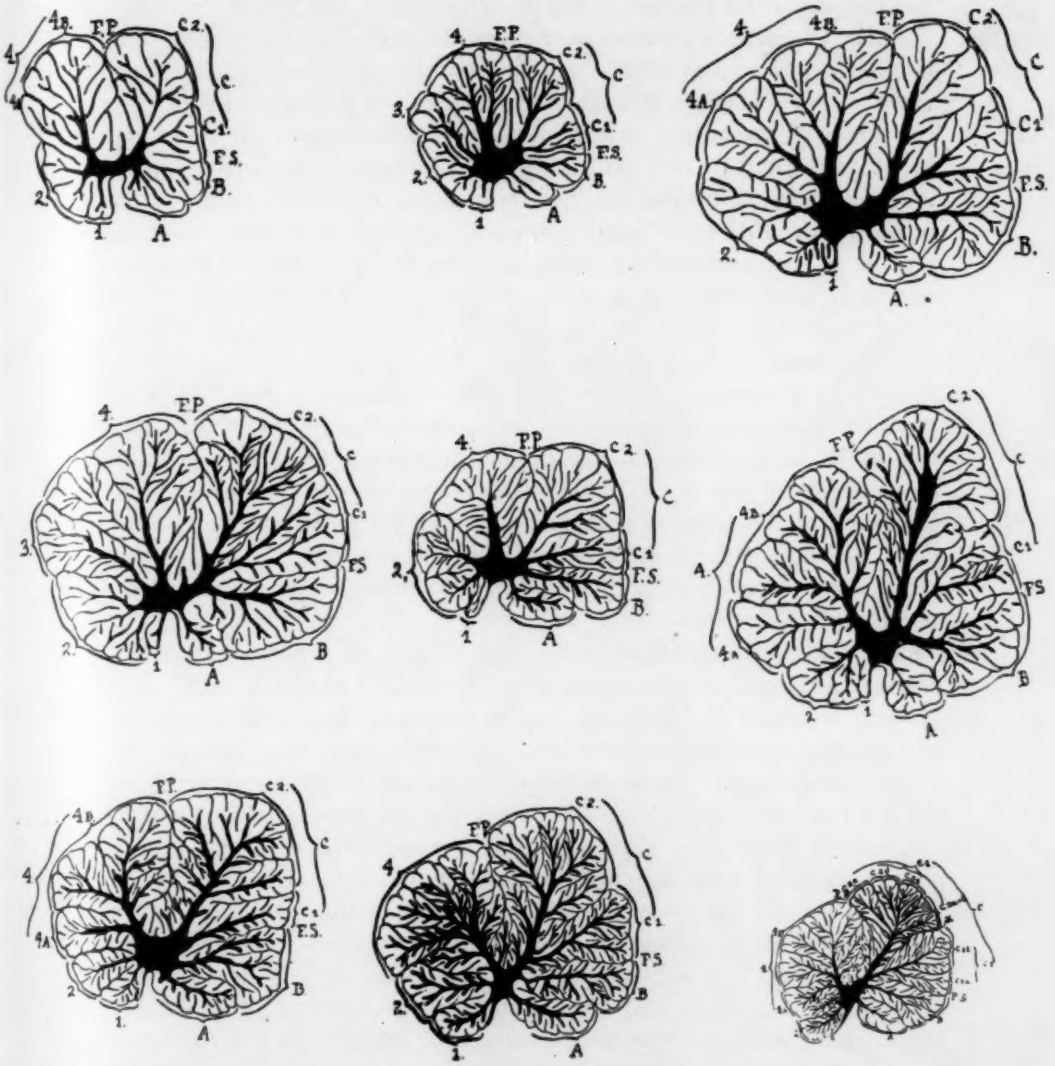

Fig. 40.—The arbor vitae of the primates in series shows the gradual evolution which has taken place in this phase of cerebellar organization. The order of precedence does not necessarily indicate the relative positions held by each member of the primate suborder, but does exemplify the advance shown by each successive form in the development of the cerebellum. The points to be emphasized are: (1) the modification in the form of the medullary substance from a transverse bar in the lower forms to the oblique triangular form in man; (2) the development of the lingula; (3) the crystallization of lobulus 4, and (4) the gradual efflorescence and emergence of lobulus C as the dominating feature in the arbor vitae.

true is difficult to determine. In a rapidly developing series showing in clear detail the gradual evolution of lobulus 4 and lobulus C, which are the characteristic portions of the primate cerebellum, there follow one another *Simia satyrus, Gorilla gorilla, Anthropopithecus troglodytes* and *Homo sapiens.* These forms are given in this sequence advisedly from the study of the arbor vitae and of the folial pattern. It seems yet to be a debatable point which of the primate forms is the higher, *Anthropopithecus troglodytes,* the chimpanzee, or *Gorilla gorilla.* The reconstructions of their brain stems and study of microscopic sections present so many conflicting points of view that it is difficult to arrive at any definite conclusion as to the relative position of these two forms in the ascent of man. In many ways the physical organization of the chimpanzee is closer to that of man than that of the gorilla. In his manner of progression, in the comparative freedom of the fore limbs from the necessities of locomotion, in his more delicate bodily structure and in his more tractable disposition, the chimpanzee attains a place more nearly in line with *Homo sapiens* than *Gorilla gorilla.* A consideration of the arbor vitae and of the folial pattern from the point of view of similarity of organization and development to the human cerebellum places *Gorilla gorilla* on a distinctly lower plane than *Anthropopithecus troglodytes.*

The development of lobulus 4 and lobulus C presents a gradual efflorescence from *Simia satyrus* to gorilla, chimpanzee and man. The gradual evolution of lobulus C, and in particular lobulus C 2, without any question, must be associated with the increasing cortical connections of the cerebellum. These pallial contributions reach the cerebellum for the purpose of enriching and perfecting the organization of skilled movements which show such a decided upward trend in *Simia,* gorilla and chimpanzee with its final culmination in man. Confirmation is added to this by the gradual accretions in size of the middle cerebellar peduncle, the great pathway by which the cortex pours its contributions to synergy into the cerebellum. The expansion in lobulus C 2 has taken place pari passu with the enlargement of the cerebral peduncle, the pontile nuclei and the middle cerebellar peduncle. Dr. Cornwall in his specimen of cerebrocerebellar agenesis has been able to follow the fibers of the middle cerebellar peduncle into the pyramidal and suprapyramidal portions of the cerebellum, which would bring them directly into the area under discussion, that is lobulus C 2, and its lateral expansion in what may be recognized as the derivatives of the lobulus ansiformis.

There can be little doubt that this regional aggrandizement is associated with the development of the motor patterns and formulas connected with the acquisition and perfection of skilled movement, which reaches its acme in the functional capacities of the upper and lower

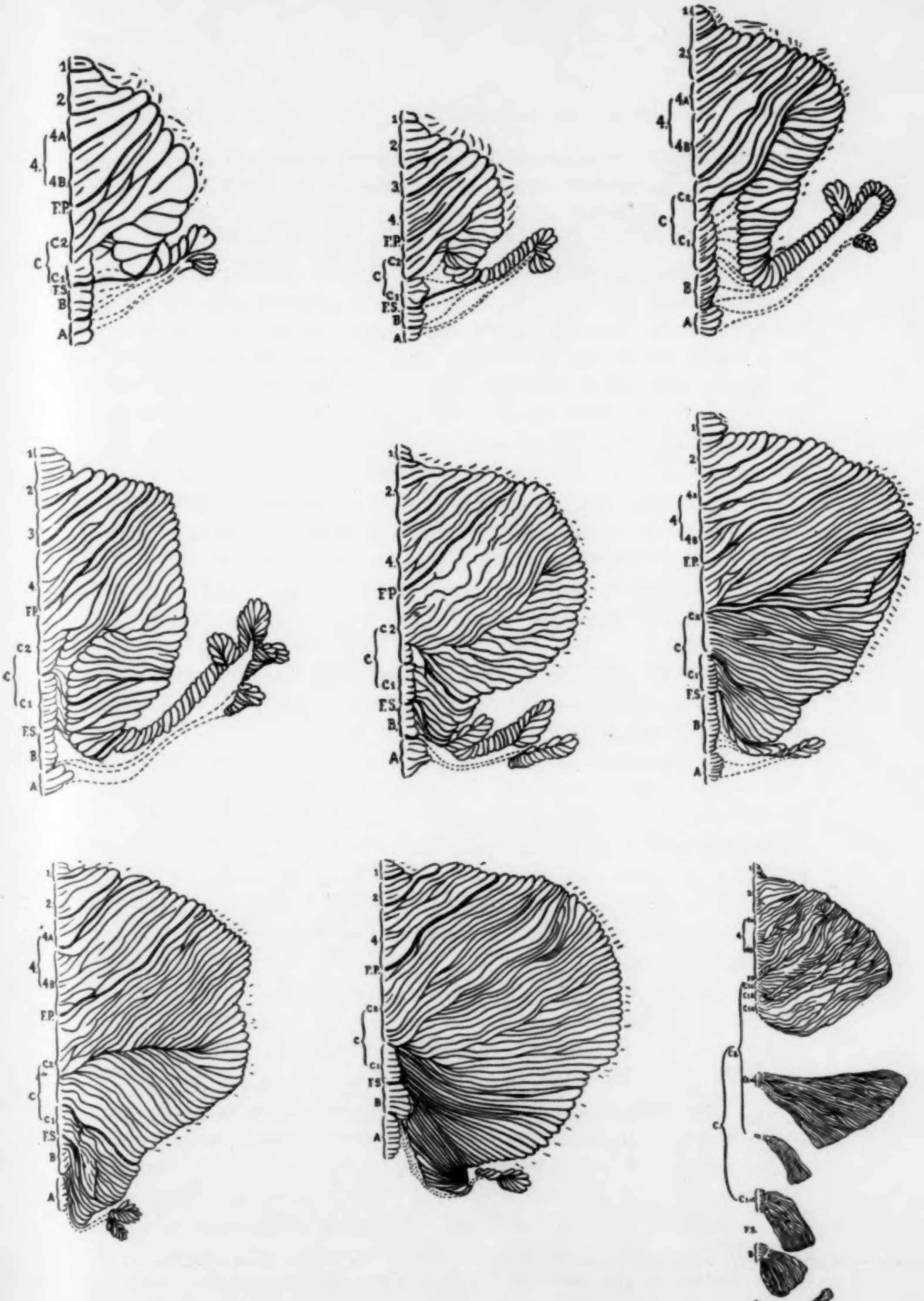

Fig. 41.—This series of folial patterns demonstrates the gradual transition through the primate series from Hapale jacchus to Homo sapiens. The features of general interest which are shown by this comparative representation are: (1) the gradual reduction of the lobulus parafloccularis and its identification with the tonsil; (2) the progressive reduction in importance of the anterior lobe as compared with the posterior lobe; (3) the gradual evolution, and final ascendancy of lobulus C and, in particular, lobulus C 2; (4) the identification of the sulcus horizontalis with the sulcus intercruralis, and (5) the much closer approximation to Homo sapiens of Anthropopithecus troglodytes than Gorilla gorilla.

extremities in their unilateral independence as exemplified by the human hand. One can quarrel but little with the conclusions that this major expansion is probably closely associated with manual differentiation and also with the undeveloped potentialities of the foot. The specialization of the foot has never received the attention which it deserved, for, as Tilney has repeatedly pointed out, the overspecialization of the primates in the development of four hands has steadily handicapped their development, and it is only after the feet have specialized in locomotion that the fore limbs have been freed from the necessities of transportation and attained the opportunity for their complete emancipation.

CONCLUSIONS

1. A modification of Bolk's cerebellar diagram and schema is presented in a division of the anterior lobe into definite vermal and hemispheral portions.

2. The division of the cerebellum into an anterior and a posterior lobe is sufficient, and no useful purpose is served by the addition of a middle lobe.

3. The arbor vitae and folial patterns show that the most cephalic and the most caudal portions of the vermis undergo the least degree of significant modification.

4. The ungulates develop a paravermis in lobulus C and lobulus B.

5. The aquatic forms show a striking uniformity in the development of the lobulus parafloccularis, and this may be associated with the specialization of the axial and appendicular musculature in the particular type of progression necessitated by an aqueous environment.

6. It is perfectly possible to homologize the various subdivisions of the human cerebellum with the accepted constituents of the schematic cerebellar pattern.

7. The sulcus horizontalis magnus appears to be the homologue of the sulcus intercruralis.

8. A definite statement cannot be made from this incomplete study as to functional localization in all of the lobules of the cerebellum.

9. This study offers but little confirmation of the accepted functional capacities of the anterior lobe of the cerebellum.

10. Lobulus 4 and lobulus C, with their associated hemispheral expansion, show the greatest progressive differentiation and efflorescence. This is definitely associated with the rôle played by the cerebral cortex in its influence over cerebellar unfolding and may be correlated with the perfection of the patterns for skilled movements and the unilateral independence of the fore and hind limbs.

11. Further elaboration of this study may present material of value in further attempts to establish functional localization in the comparative and human cerebellum.

THE CEREBRAL CIRCULATION

V. OBSERVATIONS OF THE PIAL CIRCULATION DURING CHANGES IN INTRACRANIAL PRESSURE *

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AND

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Investigation of the cerebral circulation during periods of increased intracranial pressure was given renewed impetus by Cushing.[1] He demonstrated the existence of a hindbrain regulatory mechanism and showed that partial anemia of the vasomotor center might bring about a rise in systemic blood pressure great enough to maintain cerebral circulation during excessive elevations of intracranial pressure. In addition to his manometric studies, Cushing made observations of the pial vessels through a window placed in a trephine-sawed hole in the skull in dogs. During the period of increased pressure within the skull, he noted collapse of the sagittal sinus, distention and stasis in the tributary veins, and obliteration of the arteries and arterioles, with blanching of the cortex.

Making use of a recently developed technic we have reinvestigated the effect on the pial blood vessels of large rises in intracranial pressure. Our object has been to learn by actual measurements and observation with a microscope how the blood supply of the brain is affected by measured changes of pressure within the skull.

Our observations confirm those made by Cushing and add further details of a quantitative nature.

METHOD

The method employed was described in detail in a previous contribution.[2] In brief, measurements, observations and photographs of pial blood vessels have been made, by microscope, through a cranial window in anesthetized cats. A record of the blood pressure in the femoral artery has been made at the same time.

For increasing the intracranial pressure, an apparatus similar to that used by Cushing was employed. Ringer's solution in a container was raised by means of

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1. Cushing, Harvey: Am. J. M. Sc. **124**:376, 1902; Bull. Johns Hopkins Hosp. **12**:290, 1901; Mitt. a. d. Grenzgeb. d. Med. u. Chir. **9**:773, 1902.

2. Forbes, H. S.: The Cerebral Circulation: I. Observation and Measurement of Pial Vessels, Arch. Neurol. & Psychiat. **19**:751 (May) 1928.

a pulley and string to any desired height on a graduated pole. The pressure thus obtained was communicated to the intracranial cavity through a needle in the cisterna magna or through a tube the outlet of which lay beneath the window over the parietal cortex. The Ringer's solution passed through a coil immersed in warm water so that only warmed fluid entered the cranium.

The varying rates of blood flow, though not measured, were roughly estimated by noting the varying speed of red cells through any given vessel. This has been schematically represented at the bottom of the charts.

OBSERVATIONS

Twelve cats were used for these experiments. Although in the different animals some variations in response to high intracranial pressure were seen, the usual sequence of events was as follows: until the cerebrospinal fluid pressure was raised to a height four or five times the

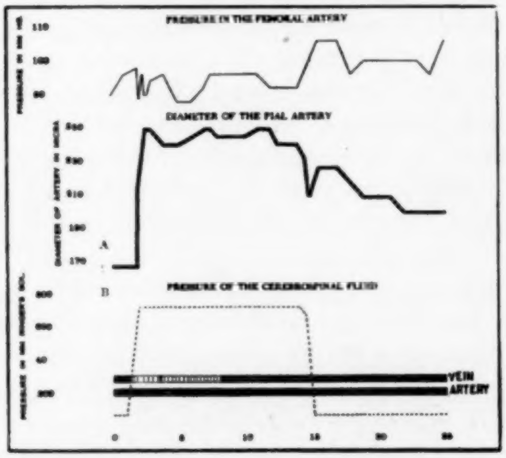

Fig. 1.—Effect on pial blood vessels and cerebral circulation of a sudden moderate increase in intracranial pressure. Arrow marked *A-B* in charts indicates probable error.

The animal weighed 4 Kg. It was anesthetized with 41 cc. of iso-amyl-ethyl barbituric acid, injected intraperitoneally. The cerebrospinal fluid pressure was raised quickly (in one minute) to a pressure of 750 mm. of Ringer's solution and kept at that level twelve minutes. Within forty-five seconds the pial artery started to dilate and within another forty-five seconds it had dilated 47.3 per cent. The pial artery remained dilated during the period of increased intracranial pressure and then, coincident with the lowering of the pressure, became constricted. The systemic arterial pressure changed but slightly during the entire experiment; the highest level reached was but 16 mm. of mercury above the initial pressure. When the cerebrospinal fluid pressure first was at its height the flow in the veins was slow. It later became more rapid.

normal, a visible change in the pial vessels did not occur; then, as the pressure was increased, there was noticed a slowing of the blood flow through the veins, dilatation of the veins, dilatation of the arteries,

slowing of the blood flow through the arteries, narrowing of the arteries and finally, complete emptying of these vessels and blanching of the cortex.

The alterations in size of pial vessels and in the rate of flow (during periods of normal blood pressure) depended chiefly on two factors: the extent to which the pressure within the skull was changed and the rapidity of the change. Raising the pressure abruptly (in one minute) to 750 mm. of Ringer's solution, resulted in a slowing of venous flow, dilatation of pial veins and a pulsating flow of blood corpuscles in the veins. The pial arteries promptly dilated (fig. 1) and stayed so until the intracranial pressure was released, after which they returned to their former size. As only minor fluctuations in systemic arterial pressure

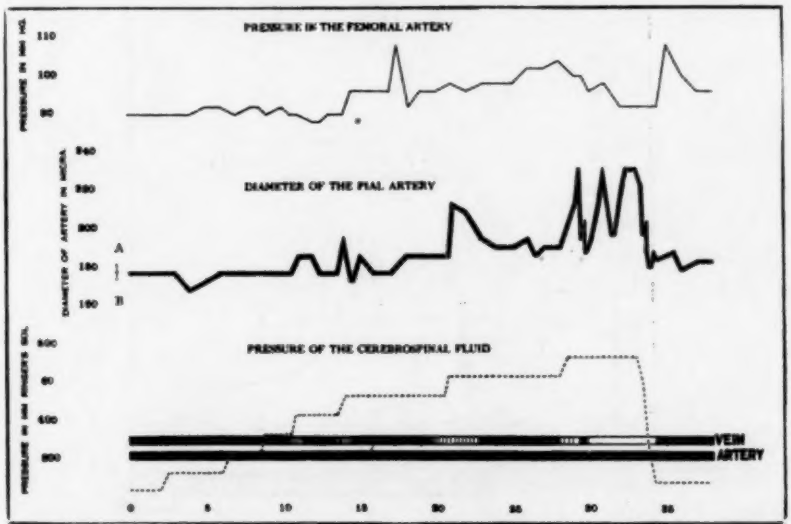

Fig. 2.—Effect on cerebral circulation of a slow moderate increase in intracranial pressure.

The animal weighed 4 Kg. It was anesthetized with 41 cc. of iso-amylethyl barbituric acid, injected intraperitoneally. The cerebrospinal fluid pressure was raised slowly to a pressure of 100 mm. of Ringer's solution about every two to seven minutes over a total period of twenty-eight and one-half minutes. The diameter of the pial artery with the exception of minor fluctuations, changed little until a pressure of 650 mm. had been reached. It then momentarily dilated and immediately became constricted as soon as the pressure was lowered to 100. During the experiment there were but minor variations in systemic arterial pressure. The greatest increase was 16 mm. of mercury, when the intracranial pressure had reached a pressure of 500 mm. of Ringer's solution. Change in the arterial flow could not be detected, but the venous flow slackened for a time after the last increase of pressure and even stopped momentarily when the cerebrospinal fluid pressure was at 750 mm. of Ringer's solution. It was fairly constant and rapid between elevations.

occurred at the time, the dilatation must have had some cause other than an increase in systemic arterial pressure. The probable cause of the dilatation will be discussed later.

Raising the intracranial pressure very slowly (in twenty-eight minutes) to the same height as before resulted in similar changes, but these occurred more slowly and with a preliminary slight narrowing of the artery (fig. 2). The slowing of pial venous flow was observed in all cases, regardless of whether the pressure was raised suddenly or slowly. Soon after the arteries dilated, the venous flow, although still slower than normal, began to increase in rate (that is, the cerebral circulation was becoming adjusted, even though the intracranial pressure was

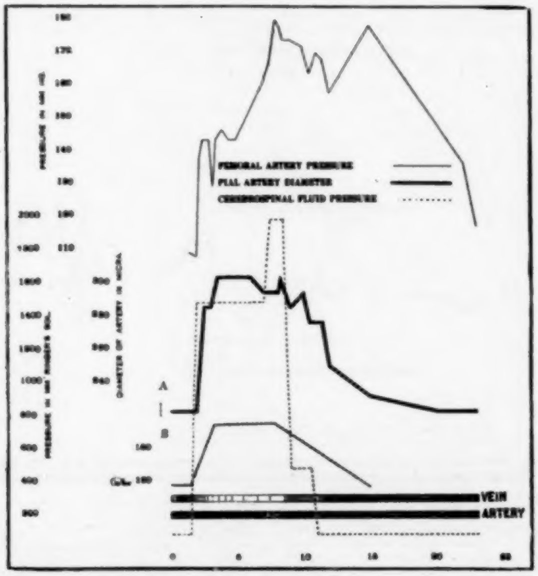

Fig. 3.—Effect on cerebral blood vessels and circulation of a sudden great increase in intracranial pressure.

The animal weighed 2.3 Kg. It was anesthetized by intraperitoneal injections of 19 cc. of iso-amyl-ethyl barbituric acid. The cerebrospinal fluid pressure was raised to 1,500 mm. of Ringer's solution in one-half minute and kept there five minutes before being further elevated 500 mm. The systemic arterial pressure rose and the pial artery started to dilate within one-half minute after the first increase in cerebrospinal fluid pressure. The artery dilated 36 per cent. The systemic arterial pressure was 71 mm. of mercury higher and maintained this level. The pial artery became constricted while the blood pressure was still elevated. The changes in the diameter of the pial veins roughly paralleled those of the pial artery. A 10 per cent dilatation occurred. The flow in both artery and vein slowed when the cerebrospinal fluid pressure was at its height but returned to normal when it was lowered.

steadily maintained at an abnormal height). When the pressure was lowered to 100 mm. of Ringer's solution, there immediately followed

a further increase in rate of venous flow and a prompt narrowing of arteries and veins (figs. 1 and 2).

If the pressure was raised to a greater height (1,500 or 2,000 mm. of Ringer's solution), in from one-half to one minute the changes already described were soon followed by emptying of some of the pial veins, by a rise in systemic arterial pressure and by further dilatation and slowing of flow in pial arteries (figs. 3, 5 and 7). When the intracranial pressure was suddenly released, the pial arteries, which had begun to show slight cyanosis, dilated still more and became bright scarlet, and the veins—previously purple—then approached the arteries in color and became dilated also and filled with blood, flowing at a rapid

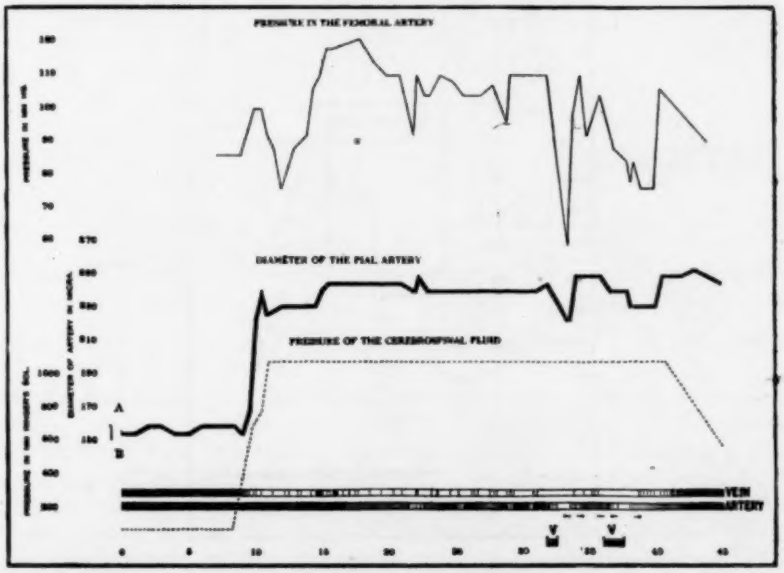

Fig. 4.—Effect of variations in systemic arterial blood pressure on the cerebral vessels and circulation during increased intracranial pressure.

The animal weighed 4 Kg. It was anesthetized with 41 cc. of iso-amyl-ethyl barbituric acid injected intraperitoneally. The cerebrospinal fluid pressure was raised within two and three-fourth minutes to 1,100 mm. of Ringer's solution. The pial artery at first became slightly constricted and then it dilated 50 per cent. The systemic arterial pressure rose. The cerebrospinal fluid pressure was held at 1,100 for thirty-one minutes. The pial artery dilated slightly and remained fairly constant. On stimulation of the vagus nerves the systemic arterial blood pressure fell, and with the fall the pial artery became constricted. During the period of great fall in blood pressure, the flow in the artery stopped and reversal occurred (arrows indicate the direction of the flow). One may note the relationship between arterial flow and systemic arterial pressure. The venous flow was also impaired throughout the period of increased pressure and stoppage occurred with cessation of the arterial flow.

pace (figs. 6 and 7). It was ten or fifteen minutes before the arteries regained their original size (fig. 3).

If, however, the intracranial pressure was held at a high level (1,100 mm. of Ringer's solution) for a longer period (thirty minutes), and a sharp fall in arterial pressure was caused by stimulation of the peripheral end of the cut vagus nerve, there resulted a narrowing of pial arteries, a slowing, and then a cessation of flow in veins and arteries and sometimes even a momentary reversal of flow in the latter. When the arterial pressure returned to its former level, the blood flow and the caliber of the vessels followed suit (fig. 4).

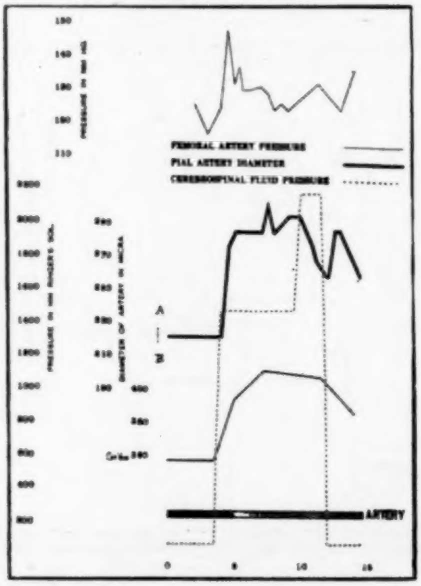

Fig. 5.—Venous dilatation and delayed arterial dilatation following abnormal increase in intracranial pressure.

The animal weighed 2.3 Kg. It was anesthetized with 19 cc. of iso-amyl-ethyl barbituric acid, injected intraperitoneally. The cerebrospinal fluid pressure was raised in one-half minute to 1,500 mm. of Ringer's solution. The pial vein immediately dilated but the pial artery did not until shortly after (dilatation 28 per cent). The systemic arterial pressure immediately rose 31 mm. of mercury. The cerebrospinal fluid pressure was raised to 2,200. The systemic arterial pressure immediately rose slightly, the pial artery became constricted and the arterial flow slowed. When the cerebrospinal fluid pressure was lowered the systemic arterial pressure fell, and whereas the blood pressure was lower than its initial level, the pial artery dilated. One should note the relation between systemic arterial blood pressure, the arterial flow and the diameter of the pial artery during the increase in intracranial pressure.

The caliber of the pial arteries thus varied in the same direction as the systemic pressure; or, if this was constant, it varied directly with

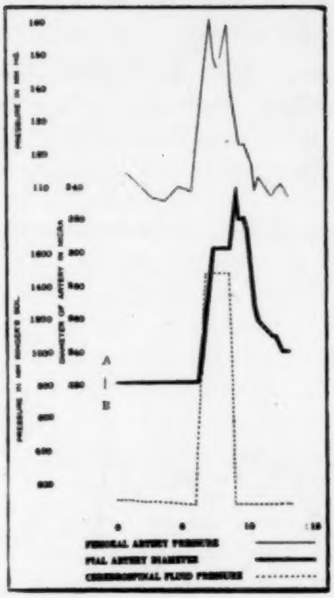

Figure 6

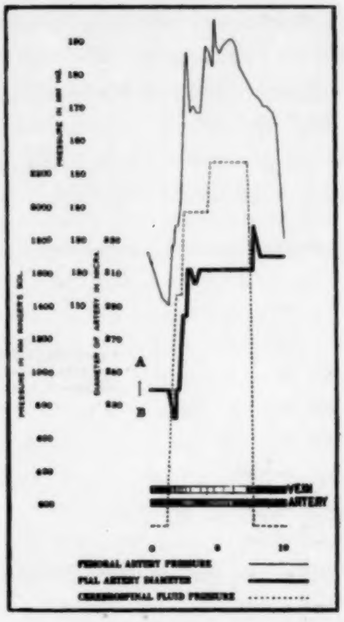

Figure 7

Fig. 6.—Delayed arterial dilatation following a lowering of the abnormal increase in intracranial pressure.

The animal weighed 3.1 Kg. It was anesthetized with 30 cc. of iso-amyl-ethyl barbituric acid, intraperitoneally injected. The cerebrospinal fluid pressure was raised in one minute to 1,500 mm. of Ringer's solution. The pial artery dilated 36 per cent, and the systemic arterial pressure rose 52 mm. of mercury. As soon as the pressure was lowered, the artery dilated 11 per cent further, although the systemic arterial pressure had already fallen about 300 mm. of mercury. The pial artery then gradually returned to normal. (See fig. 5 also.)

Fig. 7.—Delayed arterial dilatation after a period of increased arterial flow.

The animal weighed 3.1 Kg. It was anesthetized with 30 cc. of 1 per cent iso-amyl-ethyl barbituric acid, injected intraperitoneally. The cerebrospinal fluid pressure was raised to 2,200 mm. of Ringer's solution in seventy seconds, and held at this pressure for two minutes before a final elevation of 300 mm. When the intracranial pressure was first raised, the systemic arterial pressure rose 86 mm. of mercury, the pial artery became narrower and then dilated 29.6 per cent. When the cerebrospinal fluid pressure was lowered, it further dilated 8.5 per cent. The dilatation in this instance was associated with elevation in blood pressure. The flow in both artery and vein was appreciably lessened during the height of the increase of intracranial pressure but regained its initial speed when the pressure was again at 100 mm.

the intracranial pressure (figs. 2 and 8). As already mentioned, under these conditions (increased intracranial pressure for a long period) a fall in systemic arterial pressure of 60 mm. of mercury (fig. 4) caused a decided reduction in the diameter of the pial artery.

Under normal intracranial pressure, on the other hand, the diameter of the pial artery was relatively independent of changes in systemic arterial pressure. Only great fluctuation in the latter—over 60 mm. of mercury—affected the caliber of the artery, and often a moderate fall

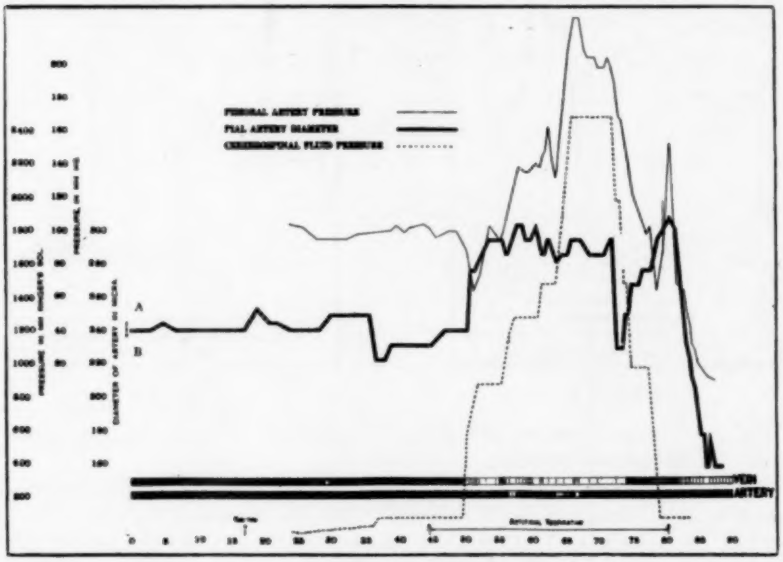

Fig. 8.—The association of impaired venous flow, fall in systemic arterial pressure and impaired arterial flow with variations in the diameter of the pial artery during a period of great increase in intracranial pressure.

The weight of the animal was 3.1 Kg. Anesthesia was obtained with 25 cc. of iso-amyl-ethyl barbicuric acid, injected intraperitoneally. After the vagus nerves had been tied, cerebrospinal fluid pressure was gradually raised to 2,500 mm. of Ringer's solution. The artery immediately became dilated and remained so (approximately 22 per cent). After the cerebrospinal fluid pressure had been at 2,500 mm. of Ringer's solution for several seconds, the systemic arterial pressure rose to 230 mm. of mercury. With fall in blood pressure, the circulation in the pial artery became slower and the vessel became constricted. The cerebrospinal fluid pressure was lowered. Pial artery dilatation continued in spite of the sharp drop in blood pressure, and was almost maximal when the blood pressure was lowest. The venous flow was slow from the onset of the intracranial pressure increase and stopped when the arterial flow stopped. One may note the relation between the diameter of the pial artery and venous flow in the first part of the pressure increase; between the diameter of the artery and systemic blood pressure when the intracranial pressure was elevated; between impaired circulation and delayed dilatation after intracranial pressure had been reduced to normal.

in arterial pressure was observed while the pial artery was dilating and vice versa. This has been noted repeatedly.[3]

The speed of blood flow, too, through the pial vessels was controlled chiefly, not by the arterial pressure alone, but by the ratio of cerebral arterial to intracranial pressure (or more exactly intracranial venous pressure, which is usually very close to it). When both these pressures were normal, the flow in a pial artery, 180 microns in diameter, was so rapid that the movement of the blood corpuscles within the artery could not be detected. It was not until the arterial pressure fell to 20 mm. of mercury or lower that the flow slowed sufficiently to become visible. When, however, the intracranial pressure was very high, the corpuscles in the same artery could be seen if the arterial pressure fell only to 60 mm. of mercury. In all cases of retarded flow the corpuscles were seen first in the smaller vessels. When the intracranial pressure was normal, reversal of flow in the arteries did not occur till the heart failed. Then the blood flowed from the head, where the pressure was about 50 mm. of Ringer's solution into the chest, where it was slightly lower. Soon the arteries became empty and somewhat narrowed, but not collapsed. If, however, the intracranial pressure was negative (less than atmospheric) when the heart failed, then the pial arteries dilated and remained filled with blood.

Under normal or low intracranial pressure a striking occurrence was noticed in every animal in which, from any cause, the respiration and circulation failed. When the systemic arterial pressure fell below 10 mm. of mercury and the circulation even in the larger arteries of the pia began to slow, and the corpuscles become more and more cyanotic, then the slightest compression of the thorax, as in gentle artificial respiration, caused a remarkable set of changes. Instantly the stagnant corpuscles in the half-filled arteries began to flow forward rapidly in the normal direction; within three or four seconds, the corpuscles in all the visible arteries turned from lilac to scarlet, and the arterial flow temporarily, at least, was reestablished. This gave a vivid illustration of the promptness with which, in asphyxia, artificial respiration brought relief.

COMMENT

At least three important physiologic mechanisms seem to be involved in the maintenance of cerebral circulation during periods of increased intracranial pressure.

First, the following adjustment probably occurs: the increased pressure of the cerebrospinal fluid is transmitted readily to the interior of the thin-walled veins, in which the pressure is relatively low. Thus

3. Forbes, H. S., and Wolff, H. G.: The Vasomotor Control of Cerebral Vessels, Arch. Neurol. & Psychiat. **19**:1057 (June) 1928.

the intracranial venous pressure is raised and the blood flow retarded. The rise in pressure in the veins is transmitted to the capillaries and then to the arterioles, raising the pressure in each. An increase in arterial pressure within the skull results, and a slower, yet effective circulation through the brain is established without any rise in systemic arterial pressure.

Second, in response to cerebral anemia, when the first adjustment is no longer adequate, there occurs a rise in pressure in the systemic arteries.

Third, a factor (which must assist the other two) is the reduction in vascular tone, or relaxation, of the vessel walls associated with asphyxia. Thus, dilatation is favored, and a greater volume of blood can flow through the cerebral vessels with less resistance than before.

Evidence for the first physiologic mechanism described is to be found in experimental and in clinical observations. Fleming and Naffziger [4] measured in dogs the pressure in the circle of Willis by introducing a cannula into the cranial end of the ligated carotid artery. Then they partially stopped the other cerebral arteries. After constant pressure and volume flow had been established, the experimenters stopped the venous outflow. The last procedure raised the pressure in the circle of Willis. It seems reasonable to conclude that this rise in pressure resulted from a sudden increase in venous pressure transmitted through the capillaries to the arterioles and through them to the larger arteries at the base of the brain.

Baillart and Berens [5] measured the pressure in the retinal artery in man, and concluded that there was increase in retinal arterial pressure in patients with increased intracranial pressure. In these cases, an increase in pressure in the systemic arteries was not observable.

A rise of arterial pressure locally within the cranium, in the presence of increased intracranial pressure, is of the utmost importance. It explains on a mechanical basis both the experimental observation that intracranial pressure may be raised to levels approaching the systemic arterial pressure without shutting off the cerebral circulation, and the clinical observation that patients with high intracranial pressure of gradual development (notably associated with tumors of the brain) can have functioning cerebral circulation together with normal systemic arterial pressure. The "Cushing phenomena" occur clinically only when the intracranial rise is sudden and marked, as in intracranial injury or in terminal stages of expanding lesions.

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4. Fleming, H. S., and Naffziger, H. C.: Physiology and Treatment of Transient Hemiplegia, J. A. M. A. **89**:1484 (Oct. 29) 1927.

5. Berens, C.: Communication read before the Association for Research in Nervous and Mental Disease, Dec. 29, 1927.

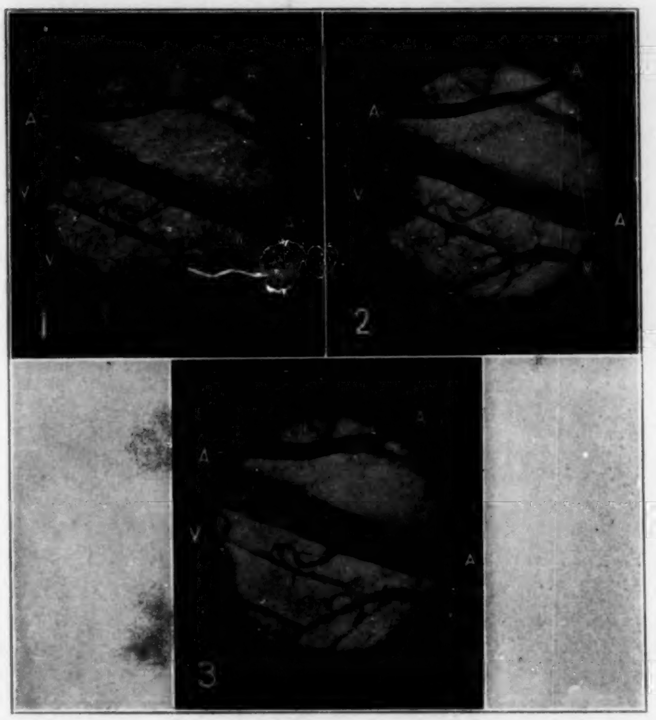

Fig. 9.—Demonstration of the effect on cerebral circulation of an elevation of intracranial pressure which is insufficient to raise the systemic arterial blood pressure. The magnification was twenty times. The time of exposure (constant) was ten seconds.

1. Control. The intracranial pressure equalled 100 mm. of Ringer's solution. The systemic arterial blood pressure was the equivalent of 88 mm. of mercury (1,197 mm. of water). The venous flow was rapid, constant and without pulsation; *A* designates arteries; *V*, veins.

2. The pial artery and veins during increased intracranial pressure (two and a half minutes after the intracranial pressure had been raised to 1,000 mm. of Ringer's solution). The intracranial pressure equalled 1,000 mm. of Ringer's solution; the systemic arterial blood pressure equalled 88 mm. of mercury. When the intracranial pressure reached 700 mm. of Ringer's solution, the cerebral venous flow became very slow, the veins dilated and the artery started to dilate. When the photograph was made (the intracranial pressure being 1,000) the venous flow was more rapid, although slower than in A, and pulsated. There was then dilatation of both arteries *(A)* and veins *(V)*.

3. After gradual decrease of intracranial pressure (eleven minutes after the stage represented in B, and eight minutes after the intracranial pressure had been returned to 100). The intracranial pressure equalled 100 mm. of Ringer's solution. The systemic arterial blood pressure equalled 88 mm. of mercury. The venous flow was not as rapid as in *A* and did not pulsate. The diameter of the arteries *(A)* was increased. The veins *(V)* were also dilated but not as in *B*. This is not as evident as it might be from the particular photographic field.

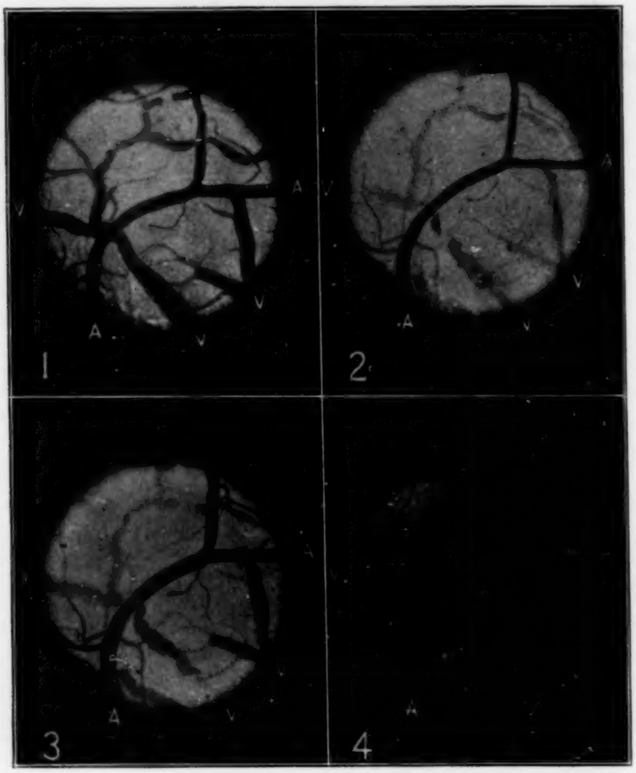

Fig. 10.—Demonstration of the effect on cerebral circulation of an elevation of intracranial pressure which is sufficient to raise the systemic arterial blood pressure. The magnification was twenty times. The time of exposure (constant) was eighteen seconds.

1. Control. The intracranial pressure equalled 100 mm. of Ringer's solution. The systemic arterial blood pressure equalled 80 mm. of mercury (1,088 mm. of water). The venous flow was rapid, constant and without pulsation. *A* designates arteries, *V* veins.

2. The pial artery and veins immediately after suddenly elevating the intracranial pressure. The intracranial pressure equalled 1,600 mm. of Ringer's solution. The systemic arterial blood pressure equalled 72 mm. of mercury (980 mm. water). The circulation in both arteries (*A*) and veins (*V*) was slower than in *A*. All the vessels were smaller. There was pulsation in the veins.

3. During the period of elevated intracranial pressure (nine minutes after the stage represented in B). The intracranial pressure equalled 1,800 mm. of Ringer's solution. The systemic arterial blood pressure now equalled 140 mm. of mercury (1,904 mm. water). The circulation was improved. The flow in both arteries (*A*) and veins (*V*) was now more rapid and both were dilated, although there was stasis in some of the veins.

4. After the intracranial pressure had been lowered. The intracranial pressure again equalled 100 mm. of Ringer's solution. The systemic arterial blood pressure equalled 64 mm. of mercury (870 mm. water). The diameter of both arteries (*A*) and veins (*V*) was increased in spite of the low blood pressure and lowered intracranial pressure. The flow was now as slow as in *A*.

It has been mentioned that after release of high intracranial pressure the dilated pial artery became still wider. The explanation of this by Cushing[6] was that the sudden removal of the supporting extravascular pressure allowed the arterial pressure—still high—to push out the vessel walls. Possibly several additional factors contribute to the same end. One of these has already been mentioned. This is the relaxation of the vessel walls, or loss in vascular tone, which occurs after partial asphyxia from any cause.[7] The cause of asphyxia here was the greatly retarded flow of blood through the pial vessels. Great dilatation, also, of the pial arteries has been observed after clamping the common carotids.[8] Inhalation of air or oxygen, to which have been added varying percentages of carbon dioxide, brings about the same result.[9]

SUMMARY

Alterations in the rate of blood flow through the cerebral vessels depend on the ratio of cerebrospinal to systemic arterial pressure (or, more truly, of intracranial venous to intracranial arterial pressure). The greater the difference in pressure, the more rapid the flow.

When intracranial pressure is raised to a great height, the following changes in pial circulation take place: slowing of the blood flow and dilatation of the veins and of the arteries. Finally, when the pressure becomes great enough to stop the cerebral circulation, the arteries become narrow and empty.

Circulation through the cerebral vessels is maintained, under moderately increased intracranial pressures, without any rise in systemic arterial pressure. It is accompanied by dilatation of cerebral arteries, and may be accounted for as follows: the rise in pressure of the cerebrospinal fluid raises the pressure in the capillaries, in the arterioles and in the smaller arteries, causing dilatation of all these vessels.

When the intracranial pressure is raised to a still greater height, the cerebral circulation begins to fail. The systemic arterial pressure then rises, and the circulation of the brain is reestablished. This compensation may occur several times if the intracranial pressure is raised by steps.

Sudden release of high intracranial pressure brings about great dilatation of pial arteries, probably largely owing to relaxation of their walls and this, in turn, is due to partial asphyxia from the previous slowing of the cerebral circulation.

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6. Cushing (footnote 1, third reference).
7. Schmidt, C. F.: Am. J. Physiol. **84**:202 (Feb.) 1928.
8. Wolff, H. G.; Forbes, H. S., and Lennox, W. G., to be published.
9. Wolff, H. G., and Lennox, W. G., to be published.

PHYSIOLOGIC MECHANISM FOR THE MAINTENANCE OF INTRACRANIAL PRESSURE

SECRETION AND ABSORPTION OF THE CEREBROSPINAL FLUID: THE RELATION OF VARIATIONS IN THE CIRCULATION *

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NEW YORK

After more than a century of speculation, the ingenious experiments of Dandy,[1] in 1919, demonstrated without question that the main source of the cerebrospinal fluid is the choroid plexus. He was able to occlude both foramens of Monro in a dog and to remove the choroid plexus from one lateral ventricle without disturbing the other. A few weeks later, the animal was killed and its brain examined. The ventricle with the intact choroid plexus was distended with fluid, while the other was collapsed and contained only a small amount of liquid similar in character to the blood plasma.

Cushing [2] had previously observed the choroid plexus through a porencephalic communication with the lateral ventricle and had seen small drops of fluid appearing on its surface.

I have seen this "sweating of the choroid" in experimental animals by direct examination with a stereoscopic microscope. Undoubtedly, certain elements are added to the fluid after it leaves the ventricles, either from the perivascular channels, which are in direct communication with the subarachnoid space, or by transudation through the walls of the capillaries on the surface of the brain. There is reason to believe that the contents of the perivascular spaces may be discharged into the subarachnoid cavity. In one instance of experimental encephalitis, I obtained a microscopic section showing a perivascular space longitudinally divided and terminating at the surface. It was packed with cells, but these were less crowded as the surface was approached, and they were evidently being discharged into the subarachnoid cavity.

If the perivascular spaces contribute to the cerebrospinal fluid, their anatomic relations are important. These relations are by no means as clear as many writers have supposed. They are usually described as a simple invagination of the pia mater of the surface of the brain carried in around the blood vessels. Were this the case, the vessels on

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* Submitted for publication, Feb. 20, 1928.

1. Dandy, W. E.: Experimental Hydrocephalus, Ann. Surg. **37**: 129, 1919.

2. Cushing and Goetsch: Concerning the Secretion of the Infundibular Lobe of the Pituitary Body and Its Presence in the Cerebrospinal Fluid, Am. J. Physiol. **37**: 60, 1910.

the surface of the brain would not have such a sheath. This, however, is not the case, with the arterioles at least, for I have frequently been able to demonstrate a perivascular space in studying the cortex with a microscope. These spaces can be made to appear by decreasing the osmotic pressure of the blood, as a result of bleeding the experimental animal and infusing physiologic sodium chloride solution, or more simply by an infusion of distilled water.

The perivascular spaces are easily visible in experimentally produced encephalitis as I have frequently observed in rabbits. In some instances, simply stroking the vessels with a cotton swab will cause them to become visible. Possibly the simplest method of demonstration is to stimulate an arteriole with the faradic current. If this is done, a sharp contraction is produced at the point of stimulation and for a short distance to either side. The perivascular space remains unaltered and outlines the former boundaries of the vessel. This contraction of the arterioles takes place without any distortion of the brain substance which would not occur were the vessels directly connected through their walls with the glial framework.

There has been much discussion as to the direction of flow of the fluid in the perivascular spaces. Is it from the interior of the brain to the surface as suggested by Weed, or in the reverse direction as believed by Mott[3]? It is conceivable that under different conditions this flow, at most extremely small in amount, might occur in either direction. The concensus of opinion apparently holds: that the cerebrospinal fluid is secreted by the choroid plexus, and that it receives certain accessions from the perivascular spaces.

ABSORPTION OF THE CEREBROSPINAL FLUID

More obscure even than the source of the cerebrospinal fluid has been its destination. It has been shown by Leonard Hill[4] that the major part of the cerebrospinal fluid undoubtedly passes into the blood. He injected methylene blue in physiologic sodium chloride solution into the subarachnoid space and recovered some of it in the stomach and in the urine within from ten to twenty minutes, while it did not appear in the lymphatic glands until after an hour or more.

It is generally conceded that cerebrospinal fluid is being constantly formed, and various methods for determining the normal secretory rate have been undertaken. It is well known that large amounts of fluid may drain away within twenty-four hours in cases in which there

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3. Mott, F. W.: The Oliver-Sharpey Lectures on the Cerebrospinal Fluid, Lancet **2**: 1 and 79, 1910.

4. Hill, Leonard: Physiology and Pathology of the Cerebral Circulation, London, J. A. Churchill, 1896.

is direct connection from the subarachnoid space to the exterior. Many observers have injected water or saline solution into the subarachnoid space in the belief that in this way they could obtain an index of the normal absorption. Duret[5] was able to inject 583 cc. of water into the craniovertebral cavity in two hours.

Falkenheim and Naunyn[6] infused physiologic sodium chloride solution through a catheter into the conus at varied pressures. At a pressure of 15 mm. of mercury there was some absorption, but it was slight. One cubic centimeter a minute was absorbed at a pressure of 59 mm. of mercury.

Dandy[7] found that from 35 to 50 per cent of dye injected into the ventricles was excreted through the urine in two hours. From this he concluded that the cerebrospinal fluid was absorbed at a similar rate. It is impossible, I believe, to make this deduction from this observation as certain substances dialyze from the cerebrospinal fluid into the blood with great rapidity, while others pass but slowly, if at all. The conditions of all these experiments are so abnormal that it is doubtful if any reliable conclusion can be drawn from them as to the rate of secretion or absorption of the cerebrospinal fluid.

There is much to support the view that under normal conditions the exchange of cerebrospinal fluid is slow. The difference in the contents of the fluid when obtained simultaneously from different loci would evidence a sluggish circulation which would not be the case were the fluid undergoing rapid secretion and absorption. The slow diffusion and unequal distribution of foreign particles such as India ink when injected into the subarachnoid spaces point to the same conclusion. It is difficult to see how a rapid exchange of this fluid could serve any useful purpose, and as its main function seems to be mechanical, stability, with but slow circulation or exchange, would seem more physiologically advantageous.

There are two main views regarding the pathways by which the cerebrospinal fluid reenters the circulation. The first hypothesis, and the one usually accepted at present, is that it is effected by passage through villus-like projections of arachnoid into the venous sinuses. This conception is supported by the excellent work of Weed. The second view is that there is a direct passage of the cerebrospinal fluid into the blood by diffusion, according to the principles of osmosis.

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5. Duret: Arch. de Physiol., Paris, 1874; Gaz. méd. de Paris, 1877, no. 49, 50 and 61; Études exper. et cliniq. cérébraux, Paris, 1878.

6. Falkenheim and Naunyn: Arch. f. exper. Path. u. Pharmakol. **22:** 261, 1887.

7. Dandy, W. E., and Blackfan, K. D.: An Experimental and Clinical Study of Internal Hydrocephalus, J. A. M. A. **61:** 2216 (Dec. 20) 1913; Internal Hydrocephalus, an Experimental, Clinical and Pathological study, Am. J. Dis. Child. **8:** 406 (Dec.) 1914.

The latter supposition has been held by Mott,[3] Dandy,[7] Blackfan and others. While it is possible that both of these pathways are utilized, I believe that the main method of exit is directly through the vessel walls.

By the injection of colored gelatin into the subarachnoid space, Key and Retzius[8] demonstrated accurately the histologic relationships of the arachnoid villi and pacchionian bodies. They were shown to be bladder or cauliflower-like excrescences of the arachnoid, which occur mainly along the course of the dural venous sinuses, and frequently encroach on the lumen of the main blood channel or in lateral diverticula. The arachnoid surface of the villi never lies free within the sinuses, and is not in direct relation with the blood.

The individual villi are saclike herniations of the arachnoid which are traversed by a network of trabeculae. Over the summit of this

Fig. 1.—"Sweating" of the choroid plexus in a cat as observed through a binocular microscope.

elevation is a fine membranous covering derived from the dura. Between the arachnoid membrane and the dural sheath is an interval which is continuous with, and part of, the subdural space.

As demonstrating the possible means by which the cerebrospinal fluid reenters the blood, important work has also been done by Weed.[9]

8. Key, G., and Retzius, A.: Anatomie des Nervensystems und des Bindesgewebe, Stockholm, 1876; Studien in der Anatomie des Nervensystems, Stockholm, 1875.

9. Weed, L. H.: Studies on Cerebrospinal Fluid; II. The Theories of Drainage of Cerebrospinal Fluid with an Analysis of the Methods of Investigation, J. M. Research **31:** (N. S., **26:**) 21, 1914; Studies on Cerebrospinal Fluid; III. The Pathway of Escape from Subarachnoid Spaces with Particular Reference to the Arachnoid Villi, **31:** (N. S., **26:**) 51, 1914; Studies on Cerebrospinal Fluid; IV. The Dual Source of Cerebrospinal Fluid, **31:** (N. S., **26:**) 93, 1917; An Anatomical Consideration of the Cerebrospinal Fluid, Anat. Record **12:** 461, 1922; The Cerebrospinal Fluid, Physiol. Reviews vol. 2, p. 171.

He injected potassium ferrocyanide and iron-ammonium citrate into the subarachnoid space. The brain was hardened in situ with a fluid containing 1 per cent hydrochloric acid. In this way, prussian blue granules were precipitated in the minute ramifications of the subarachnoid space. By this method, Weed was able to study the anatomic relationships and structure of the arachnoid villi.

Those who hold that the cerebrospinal fluid escapes from the subarachnoid space into the blood by way of the arachnoid villi believe that the passage is effected by seepage or filtration. It seems to me that this theory leaves much to be explained. In the first place, the fluid in escaping from the surface of the villus would enter the sub-

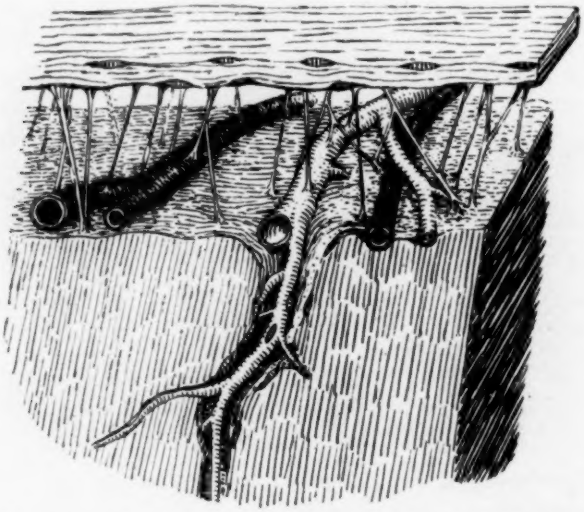

Fig. 2.—Diagrammatic representation of arterioles and venules of cortex showing continuation of perivascular sheath of venule with surface pia.

dural space and would subsequently have to pass through the dural membrane, which must offer some resistance even though it is attenuated in this locality.

In the second place, it is difficult to predicate how this seepage or filtration would be regulated or controlled. If one were to hazard an opinion as to the function of the arachnoid villi from their histologic structure and relationship, it would seem more possible that they were concerned with the entrance and exit of the subdural fluid than with the direct passage of the cerebrospinal fluid from the subarachnoid space into the blood.

In my work with hypertonic solutions, in which I employed such solutions to determine their influence on intracranial pressure, I was amazed by the rapidity of the absorption of the cerebrospinal fluid

under these conditions. Within three minutes after the injection of a concentrated solution, the pressure would commence to fall, and possibly within from twenty to thirty minutes enough cerebrospinal fluid would have been absorbed to reduce the pressure to zero. It seemed unlikely that the blood had enough contact with the cerebrospinal fluid through the arachnoid villi to effect such a rapid absorption as this. It appeared much more probable that there was a direct passage of the cerebrospinal fluid into the cortical cerebral vessels where there is a large surface of contact. Weed had previously advanced this opinion as a result of his experiments. In order to determine the possibility of this direct passage, I made the following experiment:

A trephine opening about 2 cm. in diameter was made over the cerebral cortex in a cat under ether anesthesia. The dura was opened and reflected back to the margin of the bony aperture. The arachnoid was pressed against the cortex under the margin of the bone by the insertion of bone wax. With care and the use of a microscope, it is possible to do this without at the same time shutting off the circulation in the cortical vessels. In this way, the portion of cerebrospinal fluid covering the cortex in the exposed area was cut off from communication with that in the remainder of the subarachnoid space. At this time, the arachnoid bulged slightly and presented a smooth tense surface. Twenty cubic centimeters of 1 per cent dextrose solution was then injected into the femoral vein. Within thirty minutes the arachnoid was no longer tense and even, but relaxed and irregular, draping over and outlining the cortical vessels, thus demonstrating direct absorption of the cerebrospinal fluid into the blood.

I have repeated this experiment many times, with similar results. It eliminated the participation of arachnoid villi as there were none in this locality.

OSMOTIC PRESSURE

The determination of the exact osmotic pressure of the blood and cerebrospinal fluid and its variations is beset with difficulties; little work has been done in this field. While osmotic pressure has been considered to depend on the number of molecules, ions or other particles present, this has been shown by G. M. Lewis [10] and others not to be entirely valid, especially in concentrated solutions. However, it affords a working basis for judging the osmotic relations of the blood and cerebrospinal fluid. The quantities of the osmotically active substances in the blood and cerebrospinal fluid are given in table 1. The figures are taken from Hamilton [11] and from unpublished work of Atchley of the Presbyterian Hospital, New York.

10. Lewis, G. M.: A System of Physical Chemistry, London, W. C. McC. Lewis, 1925, vol. p. 210.

11. Hamilton, Bengt: A Comparison of the Concentrations of Inorganic Substances in Serum and Spinal Fluid, J. Biol. Chem. **65**: 101, 1925.

It will be seen from these figures that the total electrolytes in the blood serum is somewhat greater than those in the cerebrospinal fluid.

In order to obtain further evidence of the osmotic relationship of these two fluids, I have made many direct determinations of osmotic

TABLE 1.—*Relationship Between Electrolytes in Blood Serum and Cerebrospinal Fluid* *

Total Base		Total Acid		Protein		Dextrose		Total Electrolytes	
Blood Serum	Spinal Fluid	Blood Serum	Spinal Fluid	Blood Serum	Spinal Fluid	Blood Serum	Spinal Fluid	Blood Serum	Spinal Fluid
164.6	156.3	137.2	145.6	15	0.006	5.5	3.3	322.3	305.2

* Values in millimols per 1,000 Gm. of water. The figures are taken from Hamilton and the unpublished work of Atchley.

Fig. 3.—Arteriole on the surface of the brain contracted by faradic current demonstrating perivascular space.

TABLE 2.—*Electrolytes in Blood Under Normal Conditions and in Pneumonia* *

Date	Total Base	Total Acid	Cl	HCO_3	PO_4	Protein	Total Electrolytes
			Normal Conditions				
	152.7	150.5	104.4	28.8	2.3	15.0	318.2
			Pneumonia				
4/19	134.7	131.0	90.6	26.3	1.3	12.8	278.5
4/26	139.5	136.6	91.8	29.1	2.3	13.4	289.5
5/ 3	146.9	145.0	100.8	26.7	2.7	14.8	306.7

* Values in millimols per 1,000 Gm. of water. The figures are taken from the unpublished work of Atchley, Presbyterian Hospital, New York.

balance of the blood and spinal fluid of patients under normal conditions. For this purpose, the blood and cerebrospinal fluid were obtained simultaneously, and always after a fast of twelve hours. The osmotic pressure of the blood is undoubtedly at its lowest point at this time,

it being subject to moderate variations due to the ingestion of sodium chloride, dextrose, etc. The specimens of blood were agitated for ten minutes to prevent clotting.

Small osmometers were devised for this purpose and made as follows:

A glass tube, about 15 cm. in length and with a bore of 3 mm., was introduced through a rubber stopper into a test tube of 12 mm. diameter. The end of the small glass tube which was to be placed in the test tube was inserted into a specially prepared celloidin sac. The rubber cork was notched in order that the atmospheric pressure would be the same in both tubes when the cork was in position in the test tube. There is no artificial membrane which has the exact permeability of normal capillaries and different membranes have been used, but celloidin membranes designated four B and six C after the formula of Krogh have been the ones mainly employed. The specimen of blood is placed in the small glass tube and celloidin sac, while the cerebrospinal fluid is placed in the test tube surrounding the dialyzing membrane. In this way I have produced an experimental capillary filled with human blood and entirely surrounded by human cerebrospinal fluid.

With these membranes separating the blood and cerebrospinal fluid for several days, there is an increase in the blood volume, at the expense of the volume of cerebrospinal fluid, thus demonstrating a higher osmotic pressure in this fluid. The passage of cerebrospinal fluid into the blood causes an elevation of the upper limit of the blood column which measures from 2 to 10 mm. or more during the first twenty-four hours.

I have made twenty-one of these determinations, and while the amount of cerebrospinal fluid which has entered the blood has varied considerably in different instances, there has not been any instance in which some of the fluid has failed to enter the blood.

If it is true that the osmotic pressure of the blood is greater than that of the cerebrospinal fluid, the cerebrospinal fluid must be constantly absorbed through the capillary walls with which it comes in contact unless the capillary membranes in this location are of different permeability than those of other portions of the body. There is no evidence of any such selective permeability under normal conditions, and so far as is known, absorption through the cerebral capillaries is subject to the same mechanism as it is elsewhere.

It may be argued that in case part of the subarachnoid space were completely walled off the contained cerebrospinal fluid would be absorbed into the blood. This undoubtedly would take place if the walls of the dural cavity could collapse, but as this cannot occur, the fluid cannot be completely absorbed without something taking its place. Under these conditions, an increasing concentration of substances which are normally present in the blood gradually occurs in the confined cerebrospinal fluid, until the character of the fluid becomes similar to

that of the plasma. How this is effected is not clear. In meningitis there is an alteration of the capillary cells which normally act as a barrier between the blood and the cerebrospinal fluid; this results in a passage of protein and other plasma constituents into the cerebrospinal fluid. This would, however, not explain the changes which take place in the fluid which is loculated by a tumor, and in which there is no evident disease of the vascular endothelium.

It therefore seems probable that the cerebrospinal fluid is constantly diffusing through the thin walls of the capillaries and veins on the surface of the brain. The rate of diffusion is dependent on the variations in the osmotic pressure of the blood. When the concentration of the blood is diminished or some of the constituents are decreased, the rate of diffusion will be much less. Should the osmotic pressure

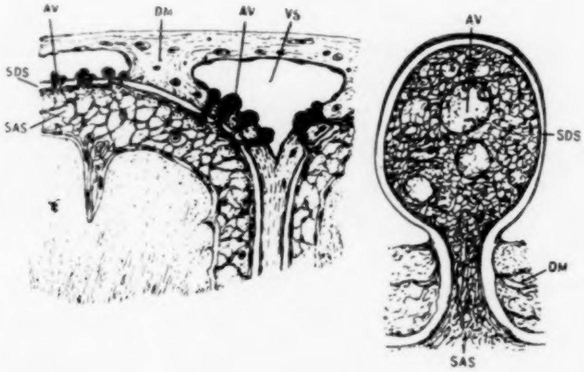

Fig. 4.—Drawings after Key and Retzius of arachnoid villi showing their relationship to the subdural space and venous sinuses. *AV* indicates the arachnoid villus; *DM*, the dura mater; *SAS*, the subarachnoid space; *SDS*, the subdural space and *VS*, the venous sinus.

of the blood fall below that of the cerebrospinal fluid, as it probably does in some instances in the early stages of pneumonia, when the chlorides are much reduced in the blood, diffusion will occur from the blood into the cerebrospinal fluid, and so-called "meningism" will result.

The protein content of the blood is probably mainly responsible for its higher osmotic pressure as compared with the cerebrospinal fluid. Increase in the protein content in the cerebrospinal fluid will lessen this differential and reduce the rate of passage into the blood. For example, in tuberculous meningitis, the cerebrospinal fluid contains a large amount of protein, and as a result of the decreased absorption into the blood there is a great increase in the amount of fluid in the subarachnoid space and in the intracranial pressure.

A similar condition occurs if the osmotic pressure of the cerebrospinal fluid is raised by a hemorrhage in the subarachnoid space, or when an injection of the serum is made into the cerebrospinal fluid.

INTRACRANIAL PRESSURE

According to my observations and experiments, intracranial tension is a composite pressure dependent on five major factors:

(1) The volume of the blood in the brain and cord and coverings; (2) the volume of the cerebrospinal fluid; (3) the volume of the cerebral axis; (4) the tension of the vertebral dura; (5) the tension of the skull.

Two of these factors are constant under normal conditions, while the remainder are variable. The tension of the cranial dura is invariable on account of its relation to the unyielding walls of the skull. The cerebrospinal axis may be distorted or displaced, but is incompressible in the sense that it is not condensible.

In 1783, Monro advanced the view that the quantity of blood within the cranium is almost invariable. If this were true, the amount of blood entering through the arteries with each systole of the heart is exactly equaled by the amount returned through the veins. This gave rise to the question, "Was the circulation through the brain a constant, even flow, or was it pulsatory?" The early physiologists, who drew conclusions from the observations of the fontanels in infants, adults with cranial defects or animals with trephine openings in the skull, believed that the brain was subject to large expansile excursions with each heart beat. They all failed to appreciate that under these conditions (that is, fontanel) there was only an elastic membrane instead of a complete, unyielding bony wall, and that variations in pressure against the skull could never produce movement or expansion. However, in the case of intermittent pressure acting on the dura unsupported by bone, pulsation would occur. Even Leonard Hill in his famous "window" experiment failed to evaluate properly the consequence of this modification. He placed a carefully sealed rubber tambour against the brain through an opening in the skull and connected this tambour with a manometer in which the pressure was equal to the intracranial tension; but he wholly overlooked the fact that in introducing an area which would respond to variations in pressure he had nullified the value of the experiment.

It seems clear that if any expansion of the dura were to occur, it would be confined to its spinal portion.

Duret was the first to demonstrate pulsation without altering the normal conditions through the introduction of an area of diminished resistance, either by removing the bony support of the cerebral dura

or by making any communication with the cerebrospinal fluid through spinal or ventricular puncture. In Duret's experiment, a tambour was placed against the occipito-atlantal ligament, and pulsation, although slight, was at one time evident. That this pulsation is slight may be judged from the fact that even when there is direct communication with the cerebrospinal fluid, as in spinal puncture, the pulsatory movement of the fluid as observed in a manometer amounts to an oscillation of only from 2 to 3 mm.

Cerebral pulsation has been supposed to favor the circulation of cerebrospinal fluid. Should this pulsation occur, it is difficult to see

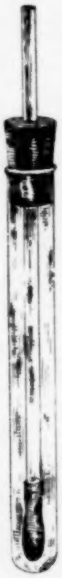

Fig. 5.—Osmometer used in determination of osmotic relationship of the human blood and cerebrospinal fluid.

how it would do more than produce a slight oscillatory movement of the fluid. With each expansion of the cerebrum, a small amount of fluid would be expelled from the rigid cerebral cavity into the spinal canal. The expelled fluid would be accommodated by a distention of the spinal dura, but with cerebral relaxation it would be returned to the cerebral cavity. Foreign particles in the subarachnoid space, such as red blood cells or particles of carbon, when observed with the microscope do not show any oscillatory or other movement. It is therefore my belief that the pulsatory movement of the cerebrospinal axis under normal conditions is extremely slight and of little physiologic importance in effecting the circulation of the cerebrospinal fluid.

In order to understand the dynamics of intracranial pressure, one should first visualize the intradural cavity without the brain or spinal cord in situ. This cavity is composed of two parts: the cerebral portion, a large but unyielding space, connected with a spinal arm which is partially elastic and allows of some distention. If such a simple chamber were filled with fluid until the distensible portion were moderately stretched, a pressure equal to that applied to the fluid by the elastic membrane would be transmitted equally to every point of the chamber. The pressure at any given point would be the thrust of the stretched membrane plus the pressure of the head of fluid above it. This explains the difference in intracranial pressure recorded in the upright and prone positions and also the variations produced by stretching or relaxing the spinal dura effected respectively by flexion or extension of the spine.

According to my measurements, the patient in the lateral, recumbent position shows a manometric elevation of cerebrospinal fluid averaging 150 mm. In the sitting position, this elevation is increased to 450 mm. The difference between the two is 300 mm. This corresponds to the actual height of the column of fluid from the cisterna magna to the point of lumbar puncture, namely 30 cm. (This, of course, is a vertical measurement and not a measurement of the length of the spine.)

This analogy, however, cannot be carried far, as the conditions in the craniovertebral cavity are by no means as simple as this; in the center of the cranial cavity is an incondensible mass through which the blood is circulating constantly, as well as a series of compartments which are more or less separated from each other.

The blood enters the brain through the large arteries at a constant pressure of about 900 mm. of water. This rises to a pressure of 1,500 mm. with each systolic contraction of the heart. As the arterioles decrease in size and increase in number, the pressure gradually falls on account of the increased friction to which the circulating fluid is subjected. The pressure in the veins averages about 150 mm. of water, while the capillary pressure is from 10 to 20 mm. higher. The capillary pressure is thus in closer relation to the venous than to the arterial pressure.

In order to study the pressure in the vessels, I have drawn out glass tubing of an original diameter of 2 mm. into small capillary points. With the aid of a microscope they can be inserted into some of the smaller arterioles and venules of the brain and the pressure measured by the method employed by Krogh. Under the conditions of this experiment, the lack of support naturally afforded the vessels on the surface of the brain, and the rapid clotting of the blood, makes

this procedure unsuitable for observations of more than a few minutes' duration. I have been able, by this method and others, to demonstrate the following facts:

1. Under normal conditions the pressure of the blood in the cerebral venous sinuses is practically the same as the cerebrospinal fluid pressure. In the human subject, the cerebrospinal fluid pressure recorded through spinal puncture in the lumbar region, with the patient in the lateral position, is practically the same as the venous pressure at the elbow.

2. Increase in the arterial pressure, as produced by clamping the abdominal aorta, produces a slight temporary rise in intracranial pressure and in the cerebral venous pressure, but its main effect is to increase the rate of blood flow.

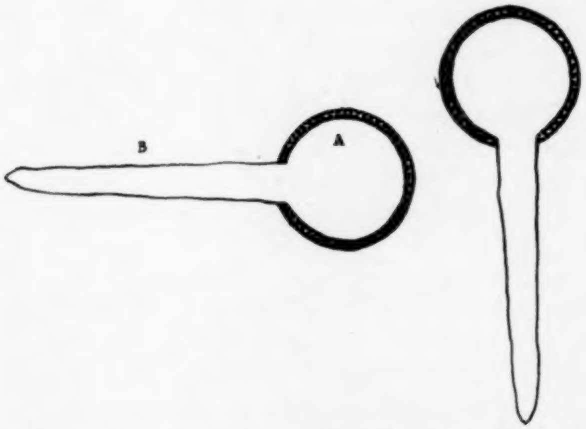

Fig. 6.—Diagram of dural cavity. *A* indicates the inelastic cranial portion; *B*, the partially distensible spinal portion.

3. A much greater rise in intracranial pressure is afforded by compression of the veins or by producing any impediment to the venous outflow. While increasing the arterial pressure may momentarily and slightly increase the amount of blood in the cerebral circulation, it cannot possibly do so to the same extent as will obstruction to the outflow.

Compression of the jugulars inhibits the escape of blood from the skull, and the increased volume of blood in the dural cavity resulting from this procedure causes a rise in the intracranial pressure. Obstruction to the general venous outflow is produced mainly in three ways: (1) experimental compression of the jugular vein; (2) compression of the right auricle by coughing, straining or any act producing a rise in the intrathoracic pressure, and (3) a generalized rise in intracranial pressure, whether through increase in the amount of fluid in the sub-

arachnoid space, or the ventricles, enlargement of the cerebrospinal axis or decrease in the volume of the dural cavity.

If the escape of blood from the cranial cavity is impeded through moderate compression of the cerebral venules, the events produced by this obstruction are as follows: There is a compression of the veins, resulting in a slowing of the velocity of circulation, and a decrease in the volume of output. This stasis in the veins produces a rise in the pressure in the capillaries sufficient to overcome this obstruction and a resumption of the circulation. As the constant arterial pressure is about six times the venous pressure, it is evident that the venous and capillary pressure can rise greatly without approaching that of the larger arteries. Should the compressing force, however, rise high enough to approach the level of the arterial pressure, there is a rise in the general arterial tension.

It may, therefore, be seen that a moderate increase in the subarachnoid pressure is quickly balanced by a similar augmentation of venous and capillary pressures. As a result of this rise in pressure, not only is there a continuance of the normal circulation, but there is no distortion of the surrounding nerve tissue which would be the case were the blood in the vessels expressed from their normal spaces. This mechanism is therefore of utmost importance in the maintenance of the normal physiologic functions. As this is the case, moderate variations in subarachnoid pressure are unimportant, and there is no sharply defined normal level in the sense that any exact and unvarying pressure must be maintained for the continuance of the normal physiologic processes. This compensating mechanism, which insures an adequate circulation despite an increase in intracranial tension, explains the possibility of the normal functional operation of the central nervous system for continuous periods in the presence of considerable increase in intracranial pressure. It must be understood, however, that this mechanism is exercised only when the compressing force is applied in such a way as to cause an obstruction to the general intracranial circulation.

4. Artificial lowering of the intracranial pressure by the removal of cerebrospinal fluid through subarachnoid puncture or by the intravenous injection of hypertonic solutions into the blood stream produces within certain limits a corresponding decrease in the venous pressure.

Theoretically, there might be a reciprocal variation in the volumes of blood and cerebrospinal fluid within the dural cavity. Increase in the amount of cerebrospinal fluid might be compensated for by an equal diminution in the blood in the cerebral circulation. It has been shown in the preceding discussion, however, that this is not the case, at least not when the volume of increment of cerebrospinal fluid is

not large. Were there a decrease in the volume of blood equal to the accession of cerebrospinal fluid, there would obviously be no increase in intracranial tension, and a distortion of the nerve tissue due to the alterations in special relationship would result.

Up to this point, I have been considering the relationships of generalized increased intracranial tension. A local compressing force may from the first have two consequences: 1. From the addition to the volume of matter within a closed space, it may cause a generalized increase in pressure with its eventualities. 2. Through local compression, it may obliterate or impede the circulation in the veins and capillaries within its immediate vicinity. This stasis will not of itself cause the increase in back pressure noted in a generalized increase in

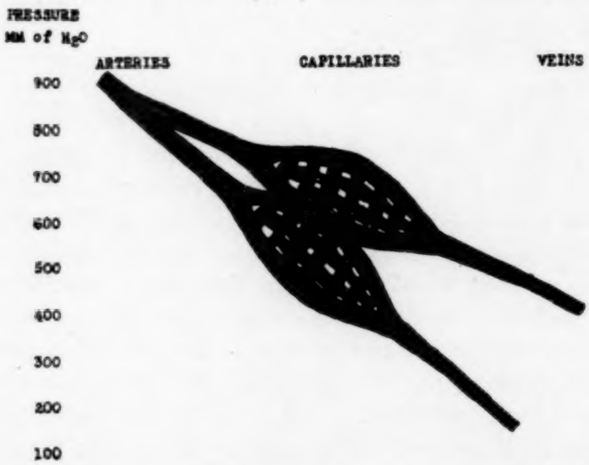

Fig. 7.—Diagrammatic representation of the arterial, capillary and venous pressures under normal conditions and the rise produced by obstruction to the venous outflow.

intracranial tension, as there is little or no obstruction to the general venous outflow.

If the mass of the compressing element is large enough to cause an increase in intracranial tension, with a rise in pressure in the head waters of the circulation, it may be of local advantage, as this increased vis a tergo may aid in the reestablishment of the circulation in the locally compressed vessels.

As long as the brain is surrounded by a continuous mantle of fluid, the pressure relationships of a hydraulic chamber continue and the brunt of the local pressure effects may be somewhat modified by the general increase in intracranial tension. This is one of the reasons why the general symptoms of intracranial pressure so frequently antedate the focal manifestations in instances of tumor.

When, however, in the case of neoplasm, the local enlargement of the brain becomes sufficient to fill its dural chamber, and express the fluid from its position over the cortex, the hydraulic principle fails, and the pressure in this chamber can no longer be measured by the pressure of the cerebrospinal fluid obtained through spinal or cisternal puncture. At this period, the local circulation may be seriously impaired and focal symptoms may rapidly develop.

I have given so much consideration to the serious effects of cerebral compression that sight may be lost of the fact that normal function may continue for long periods with considerable elevation of intracranial pressure. This is the case when the pressure is equally applied and the free circulation of the cerebrospinal fluid is unimpaired, as may occur in serous meningitis. It is the uneven application of pressure which gives rise to distortion of the local circulation, rather than actual increase in tension, which is mainly responsible for pathologic changes. The one locality in which distortion and compression may occur with increased intracranial pressure, even though the pressure is evenly applied within the skull, is the optic nerve. Here the anatomic relationships are such that it is impossible to balance the increase in pressure within the cranium by a similar force over the nerve head.

In this connection, it may be noted that the diagnostic localization of tumors will continue to be imperfect until it is more fully realized that in many portions of the brain the infiltrating neoplastic cells produce little or no local destruction of the nerve elements. The actual physiologic disturbance is due to distortion and alteration of the circulation. It is these remote distortion effects which account for the extensive physiologic disorganizations so frequently observed in the late stages of tumor of the brain. More study must be given to the arrangement of the vascular structures of the central nervous system and to the distant deformities resulting from the neoplastic enlargement of individual portions of the brain.

SUMMARY AND CONCLUSIONS

1. The cerebrospinal fluid is secreted mainly by the choroid plexus, but also receives some additions from the perivascular channels communicating with the subarachnoid space on the surface of the brain.

2. The cerebrospinal fluid is reabsorbed into the blood by diffusion through the vessel walls. This is effected by the difference in the osmotic pressure of the two fluids.

3. In inflammation of the meninges, there is a disorganization of the capillary cells which are ordinarily impermeable to certain substances in the blood, with the result that they pass into the cerebrospinal fluid.

4. The normal pressure is maintained by the secretion of sufficient cerebrospinal fluid to distend the spinal dura moderately.

5. The intracranial pressure is roughly equal to the venous pressure, and, within limits, variations in the pressure in either the cerebrospinal fluid or the venous blood are accompanied by similar directional pressure changes in the other fluid.

6. The normal cerebral arterial pressure is about six times the venous pressure. Increase in the intracranial pressure by augmentation of the amount of fluid in the subarachnoid space causes a compensating rise in the venous pressure. This in turn causes a rise in the capillaries and arterioles, and eventually in the general arterial pressure.

7. As a result of this compensatory mechanism, the cerebral circulation can be maintained when the intracranial pressure is increased.

ACUTE SWELLING OF THE OLIGODENDROGLIA AND GRAPELIKE AREAS OF DISINTEGRATION *

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Since the first article of Buscaino [1] concerning the appearance of a new type of pathologic lesion which the author called "grapelike areas of disintegration," because they resembled a bunch of grapes (fig. 1), the attention of numerous workers has been directed toward the investigation of the real nature and significance of these areas. The presence of these areas in pathologic brains was soon confirmed by many authors, among whom I will mention only Salustri,[2] d'Antona,[3] Bolsi,[4] Insabato, de Lisi, Ansalone,[5] Barbieri [6] and myself.[7] They consist of small foci, grouped together like a bunch of grapes, and they contain birefracting metachromatic coagulum which Buscaino calls substance "X."

The grapelike area was first thought by Buscaino to be an expression of a true process of disintegration due to primary lesions of the nerve fibers and eventually also of nerve and neuroglia cells. In his first articles Buscaino also claimed that these areas constituted part, at least, of the anatomic substratum of dementia praecox. Since then, these formations have been found in many other brain diseases, and Buscaino [8] was obliged to enlarge his interpretation of their pathologic significance by accepting their presence in the extrapyramidal diseases. Buscaino

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* Submitted for publication, April 15, 1928.

1. Buscaino, V. M.: Le cause anatomopatologische delle manifestazioni schizofreniche nella demenza precoce, Riv. di patol. nerv. **25:** 197, 1920-1921.

2. Salustri, E.: Sulle cosi dette zolle di disintegrazione a grappolo, Riv. sper. di freniat. **48:**255, 1924.

3. D'Antona, S., and Vegni, R.: Reperto anatomo patologico in un caso di encefalite epidemica cronica, Policlin., Sezione medica, 1922, vol. 29. D'Antona, S.: Sulla genesi delle cosi dette zolle di disintegrazione a grappolo con partocolare riguardo all'azione dell'alcohol sul tessuto nervoso, Rassegna di studi psichiat. **13:**501, 1924.

4. Bolsi, D.: Studio anatomopatologico di un caso di demenza precoce, Rassegna di studi psichiat. **14:** 37, 1925.

5. Ansalone, G.: Contributo alla istologia patologica della demenza precoce, Il Cervelo, 1923, vol 11; Riv. sper. di freniat. **48:** 208, 1924.

6. Barbieri, P.: Il significato dell'istammina nella patogenesi demenza precoce, Riv. sper. di freniat. **48:** 696, 1924.

7. Ferraro, A.: Sulla genesi delle cosi dette zolle di disintegrazione a grappolo, Arch. gen. di neurol. psich. e psicoanal. **7:**183, 1926.

8. Buscaino, V. M.: Lesioni provocate dall'istammina nei centri nervosi del coniglio, Riv. di patol. nerv. **27:**641, 1922.

considered the cause of the grapelike areas to be the presence of abnormal amines circulating in the blood.

To confirm this point of view, Buscaino devised a special reaction for the urine which he called the black reaction, and which is based on the reduction of silver nitrate solution. He claimed that this reaction, which is due to the presence of abnormal amines (histamines), is always positive in dementia praecox. The presence of abnormal amines circulating in the blood he related to constant lesions of the intestinal tract which he described in cases of dementia praecox. Furthermore, this author established by experiment that the grapelike areas of disintegration appear in the brains of animals experimentally intoxicated by histamine. They are to be found especially in the white substance and in the region of the basal ganglia.

Soon after the publication of Buscaino's papers, objections started to accumulate rapidly both in Italy and elsewhere. The objections coming from abroad were apparently based more on impressions than on observations, but in Italy special studies were undertaken to elucidate the real significance of such lesions. The two most significant objections which have been raised to the pathologic significance of the grapelike areas are the following: (1) their absence in frozen sections in contrast with their frequency in tissue treated with alcohol and especially with nitric alcohol (absolute alcohol, 100 cc., nitric acid 5 cc.); (2) their presence in brains of apparently healthy men and animals.

Because of these facts, Salustri and Ansalone concluded that the grapelike areas are artefacts produced by the action of the alcohol and are comparable to the concretions described by Rosin [9] and Nissl.[10]

S. d'Antona performed a series of experiments in order to determine the action of alcohol on the nerve tissues and reached the conclusion that the material forming the grapelike areas is a mixture of different lipoids originating in the myelin sheaths and that they thus are artefacts. Abroad, especially in Germany, the comments on the work of Buscaino also indicated that the grapelike areas were considered as artefacts (Creutzfeldt-Bielschowsky [11]).

Their presence in the brains of normal persons is also held to disprove their pathologic significance. Barbieri, in Italy, reported a case in

9. Rosin, G.: Ueber eine neue Farbungsmethode des gesamten Nervensystems, Neurol. Centralbl. **8**:98, 1893.

10. Nissl, F.: Ueber Rosin's neue Farbmethode des gesamten Nervensystems und dessen Bemerkungen über Ganglienzellen, Neurol. Centralbl., 1894. Ehrlich and Weigert: Nervensystems, in Enziklopadie der mikroskopischen Technik, Berlin, 1903, vol. 11.

11. Bielschowsky, M.: Review of Buscaino's work, Zentralbl. f. d. ges. Neurol. u. Psychiat., 1920; Review of Bailey and Schaltenbrand's article, Zentralbl. f. d. ges. Neurol., Sept., 1927, 604.

which such areas were found in the brain of a healthy man who was murdered. Bielschowsky recently reported the case of an executed criminal, free from pathologic manifestations, in whom numerous grapelike areas were present in the brain.

While this investigation was proceeding in Italy, Grynfeltt,[12] in France, described in some special conditions (senility) the appearance in the brain of mucoid substance with grapelike arrangement. The paper

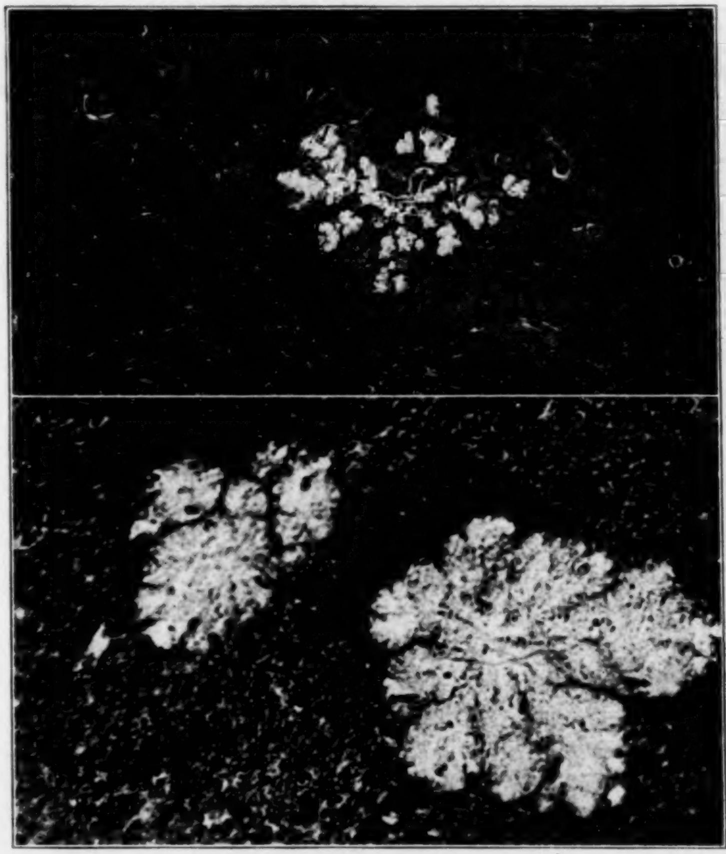

Fig. 1.—Grapelike areas of disintegration from the brain of a chicken suffering from avitaminosis; Mann stain.

read by Grynfeltt in December, 1922, did not mention the work of Buscaino, and because of lack of illustrations the identity or analogy of his mucocitic degeneration of the neuroglia with the grapelike areas

12. Grynfeltt, E.: Mucocytes et leur signification dans les processus d'inflammation chroniques des centres cérébraux spinaux, Compt. rend. Soc. de biol. **89**: 1264, 1923.

of disintegration of Buscaino could not be established. In 1924, a pupil of Grynfeltt, G. Pelissier,[13] described a wilsonian syndrome following epidemic encephalitis which presented the peculiar lesion of the mucocitic degeneration of the neuroglia. The illustrations which accompanied the paper did not leave any doubt as to the identity of the lesions described by Buscaino and those described by Grynfeltt and Pelissier.

Grynfeltt and Pelissier also mentioned the presence in the mucocitic areas of a coagulum which stains metachromatically with thionin and with the elective stains for mucine, i.e., mucicarmine and mucihematein. Because of these staining properties, the two French authors thought the material to be mucine, and they characterized the areas as "mucocite." They also tried to establish the origin of the "mucocites," and reached the conclusion that they were the result of confluence of neuroglia cells undergoing a special process of degeneration. The specific element involved by this peculiar form of degeneration was supposed to be the interfascicular type of neuroglia cell, that is, the oligodendroglia cell (del Rio-Hortega). According to Pelissier, the degeneration consists of a gradual swelling of the oligodendroglia cells in which mucine appears, and, as many of the oligodendroglia cells fuse and eventually rupture, they give rise to the so-called "mucocite" which is free mucinoid material originating from the degenerated cells. The same objections raised against the grapelike areas may be presented against this conception of Grynfeltt and Pelissier—they are present in normal brains and do not appear in frozen sections.

In my own work I devoted attention to the appearance of concretions in frozen sections treated with alcohol of from 70 to 80 per cent concentration. Following the action of the alcohol for twenty-four or more hours, the frozen sections, of material previously fixed in formaldehyde, disclose the presence, all over their surfaces, of small round, oval or polylobate bodies (fig. 2) which appear similar to the grapelike areas present in embedded material. These concretions appear monorefractile by the polarizing microscope, and they stain metachromatically with thionin, blue with Mayer's mucihematein, yellowish with Ziveris fluid, red with borax carmine, red with acid fuchsin, red with scharlach R and blue with nile blue sulphate. They are soluble in chloroform, ether and pyridine, slightly soluble in acetone and absolute alcohol and partially soluble in xylol.

It is important to mention that the physicochemical properties of these concretions are identical with those of the concretions which I found free in the alcohol used as a fixative for fresh tissue or tissue

13. Pelissier, G.: Syndrome Wilsonien consécutif à la névraxite épidémique, Contribution à l'étude de la degenerescence mucocytaire de la névroglie, These de Montpellier, Imprimerie l'Abeille, 1924.

previously fixed in formaldehyde. These concretions lie at the bottom of the bottle and may be studied by decanting the alcohol. Concretions are also found all over the cut surfaces of the blocks and may be scraped off for study. If the alcohol contains nitric acid, the number of concretions is greater and they are more typically granular. Besides the concretions, crystals are found in the alcohol the morphology of which is that of cholesterol.

I also studied the appearance of concretions in frozen sections cut from blocks previously fixed in nitric alcohol or absolute alcohol. In

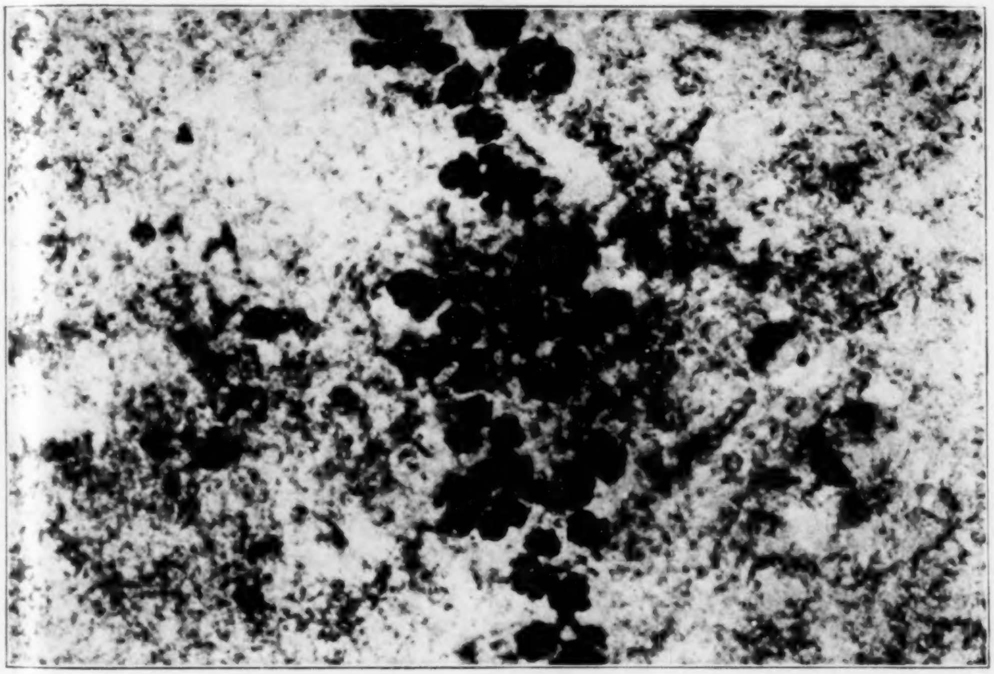

Fig. 2.—Concretions formed on a frozen section of formaldehyde-fixed material treated with alcohol for forty-eight hours; nile blue stain.

this case the concretions, besides assuming the morphologic characteristics already mentioned in frozen sections subsequently treated with alcohol or in the sediment of fixative alcohol, are larger and show a typical grapelike formation closely resembling the grapelike formations which are to be found in the embedded material. They are found both within the section itself and adherent to it. As in the embedded tissue, the grapelike areas show the presence of a central coagulum, the staining properties of which are analogous to those of the concretions found in the fixing alcohol. In the grapelike formations located outside the section, a coagulum or substance "X" of Buscaino can be seen surrounding

one or more neuroglia nuclei. Some of the areas appear as if they were superimposed on the sections while others are present in the depths of the section itself. The areas appear to be especially numerous around the blood vessels, where they seem to occur in the perivascular spaces. I concluded from these investigations that the grapelike areas shown in the frozen sections from material previously fixed in alcohol, or better, in nitric alcohol, are identical with the grapelike areas found in embedded material and that their origin is the same as that of those present in the fixing alcohol or in the frozen sections of formaldehyde-fixed material which have undergone the action of weak alcohols.

As a further step in my investigations, I reached the conclusion by the study of the transitory forms that the origin of the grapelike areas can be traced from the material constituting the myelin sheaths. The fact is easily detectable by the study of sections cutting the axis cylinders longitudinally which show that the material surrounding the axons may assume a multilobate appearance or a still more complicated structure approaching more and more the typical grapelike arrangement. Some of the nerve fibers may cross the grapelike area and impress on it a fibrillar appearance. Besides this fibrillar type, I have observed a different stage in which the coagulum does not bulge between the surrounding nerve structures, but assumes a flat arrangement. This I have called the flat type of grapelike area. Still another type consists of numerous nuclei surrounded by the same coagulum, and this I have called the nuclear type of area.

When the substance "X" of Buscaino is present between the nerve fibers all over the section, especially in the region of the internal capsule, the grapelike areas are not distinguishable but are marked, so to speak, in the general loose appearance of the tissue. This peculiar aspect of the tissue, I called loosening of the tissue (smagliatura del tessuto), and the material which distends the parenchyma is of the same type as that which forms a typical grapelike area (fig. 3).

Another point which I established is the relationship of the grapelike areas to the presence of holes in the sections. I have been able to follow transitory stages between the grapelike areas, especially the small ones, and holes which in some cases may originate from the solution of the material of the areas.

I have never been able to find a true grapelike area in frozen sections of formaldehyde-fixed material on which the alcohol had not acted. This statement is important because it establishes beyond doubt that the grapelike areas are not present unless the tissue undergoes the action of alcohol. What the action of the alcohol is, is difficult to establish. It may dissolve some of the lipoid substances or, on the other hand, because of the presence of nitric acid it may coagulate some of the proteins, the combined action resulting in the appearance of the peculiar substance "X".

My investigations led me to conclude that the grapelike areas of Buscaino are identical with the "mucocite" formation of Grynfeltt and Pelissier. This identity has since been accepted. This is important since all that I have said in reference to the grapelike areas must also be applied to the "mucocites" of Grynfeltt and Pelissier.

Is one at present justified in calling either the grapelike areas of disintegration or the mucocitic degeneration of the neuroglia merely artefacts? I do not think so. It is true that they do not appear in

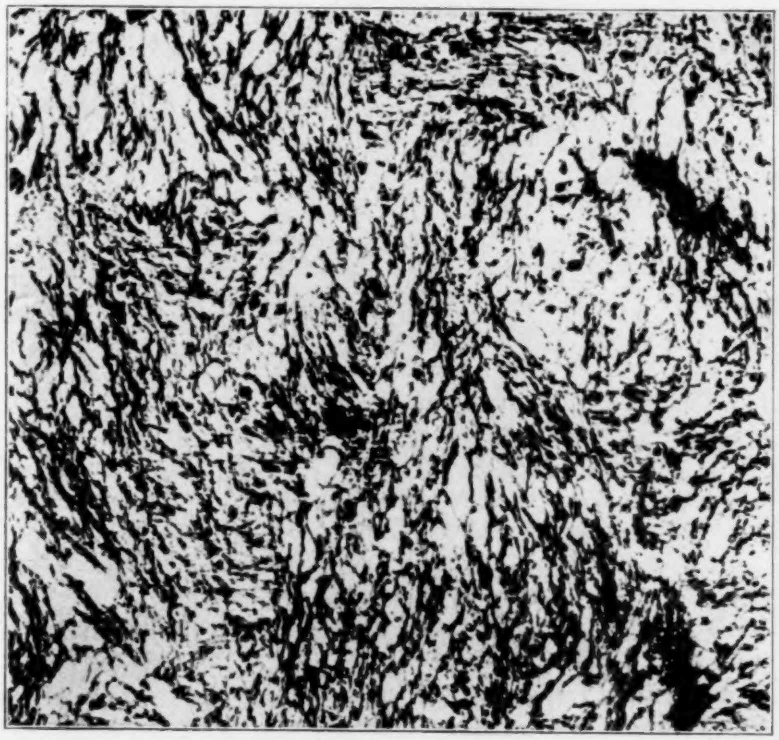

Fig. 3.—Loosening of the tissue in the internal capsule area in the brain of a case of dementia praecox; Alzheimer-Mann stain.

frozen sections, but this fact may prove only that they do not correspond to lesions of any morphologic component of the nerve tissue. They are not present in the tissue before it is exposed to the action of the alcohol, which establishes their dependence on the action of the alcohol (especially of nitric alcohol), but there is a difference between this statement and that the grapelike areas are artefacts pure and simple.

It is possible that alcohol acts as a special sensitizer of otherwise undemonstrable lesions. In other words, the alcohol may act on some product of disintegration of the lipoid or protein components of the

myelin sheaths or of the intermolecular substance, and reveal them as the grapelike masses. One may be dealing here with chemicophysical changes of the nerve substance for which there are as yet no appropriate methods.

Before using the term artefact, I think that one must exclude this possibility and until that time must assume an attitude of open mindedness, directing efforts toward the solution of this angle of the problem. Little is known about the histochemistry of the brain and the metabolism of normal and pathologic tissues. Buscaino himself recently expressed the opinion that one may be dealing with histochemical changes which require the action of a special sensitizer, such as alcohol.

The second objection to the pathologic nature of the grapelike areas is the fact that they are present in the brains of normal animals and, as pointed out by Barbieri and Bielschowsky, in apparently normal human brains.

I am inclined to consider this side of the problem from a quantitative angle. The fact that in normal brains grapelike areas are found does not clearly establish the artefact nature of these structures. It is possible that even in normal brains there may be areas in which the metabolism is to some degree affected but not enough to interfere with normal functioning. One often finds in somatic pathologic conditions areas of more or less significant lesions in a grossly normal organ without clinical expression. May not this also be true in the nerve tissue?

In cases in which grapelike areas occur in apparently normal brains, the study of their occurrence must be quantitative. It will be necessary to establish the quantitative relation between them and those of pathologic brains. This line of investigation may enable one to establish what significance should be attached to their presence in pathologic brains, independently of their origin.

The discussion rested at this point when Bailey and Schaltenbrand [14] published a paper dealing with the so-called swelling of the oligodendroglia. They concluded that the swelling of the oligodendroglia is identical with the mucocitic degeneration of the neuroglia described by Grynfeltt and Pelissier.

In 1925, Penfield and Cone [15] had described a peculiar lesion of the oligodendroglia which they termed "acute swelling of the oligodendroglia." This special lesion exhibited a gradual swelling of the cytoplasm of the oligodendroglia cells (fig. 4) which at its height may be followed by the breaking up of the cell and disintegration.

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14. Bailey, P., and Schaltenbrand, G.: Die muköse Degeneration der Oligodendroglia, Deutsche Ztschr. f. Nervenh., **97**:231 (May) 1927.

15. Penfield, W., and Cone: Acute Swelling of Oligodendroglia, Arch. Neurol. & Psychiat. **16**:131 (Aug.) 1926.

The swelling of the oligodendroglia appears in the most various pathologic conditions—tuberculous meningitis, malnutrition, acute anterior poliomyelitis, cardiac insufficiency, hydrocephalus, cerebral embolism, cerebral abscess, etc.—and, according to Penfield and Cone, represents a specific reaction of the oligodendroglia cells which was formerly vaguely mentioned in Rosenthal's work as the preameboid change. It must be said, however, that the preameboid change has nothing to do with the ameboid transformation of the astrocytes, as Rosenthal meant to point out changes occurring in the small round glia cells or satellite cells (i. e., oligodendroglia).

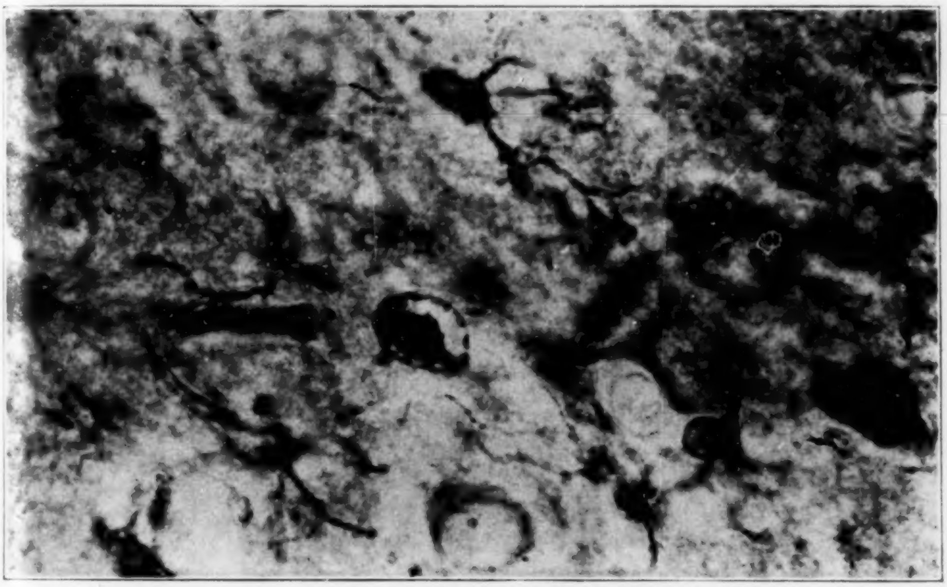


Fig. 4.—Swelling of the oligodendroglia following removal of the brain cortex in a cat; del Rio-Hortega silver carbonate impregnation.

In figure 5 (after Penfield and Cone), the different stages of the swelling are reproduced. In B are shown the earliest changes from the normal which seem to be an irregular increase in perinuclear cytoplasm. Next, swelling of the cell body begins. Unstained fluid pushes out the cell membrane (C and D) and granules are seen on the surface of the membrane and on the septums or protoplasmic girders which separate the vacuoles within the cell body. The expansions decrease in number and are represented by chains of granules. Finally, in extreme cases, the cell membrane ruptures or disappears and the nucleus appears naked (G and H). The nuclei vary considerably in the different stages, staining with greater or less intensity, but in general, there is a progressive shrinking and pyknosis.

The process ends in cell destruction only if it runs its full course, but it is apparently a reversible phenomenon. That the process is reversible was borne out by the fact reported by Penfield and Cone that several of their experimental animals in whose brains the change was present when they were killed were probably capable of making a full recovery.

Acute swelling may be caused purely by autolytic conditions, but proof that the change occurs intra vitam is to be adduced from the fact that it was found in several animals which were killed by carotid

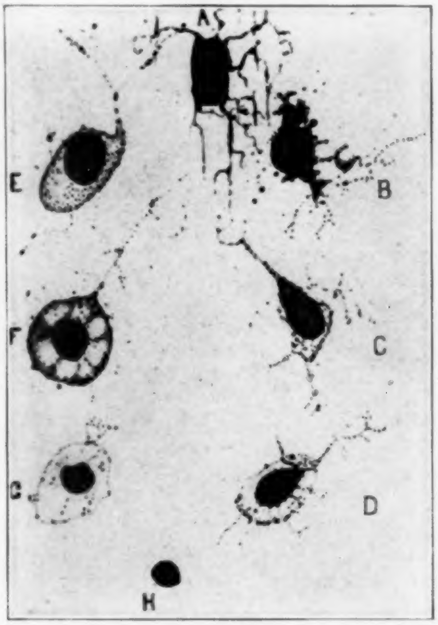


Fig. 5.—Gradual swelling of the oligodendroglia (after Penfield and Cone).

injection of the fixative and also in pieces of brain which were removed from an animal by operation and fixed immediately.

Although similar in certain ways to clasmatodendrosis, acute swelling of oligodendroglia appears before any change in the astrocytes and often is the only evidence of a pathologic change discoverable in the brain. In their paper Penfield and Cone do not mention any mucinoid substance present in the cell body of the swollen oligodendroglia.

Bailey and Schaltenbrand were able to detect a large amount of mucinoid material in the brain from a case of Schilder's disease and according to their report they have been able to follow the gradual mucocitic degeneration of the oligodendroglia cells. Their data appear, however, from the text of their paper, to be the result of comparative

studies of slides stained for mucine with slides stained by the del Rio-Hortega method for oligodendroglia cells. The conclusion they draw is that the acute swelling of the oligodendroglia cells and the mucocitic degeneration of the neuroglia are identical, that is, different degrees of the same process.

My impression is that such a statement may mislead investigators as to the significance of the so-called grapelike areas and mucocitic

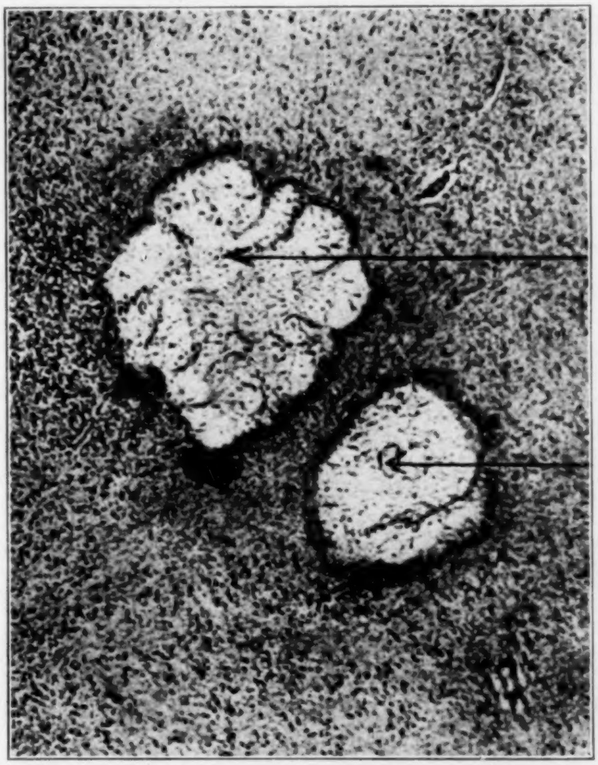


Fig. 6.—"Mucocite" of Grynfeltt-Pelissier (after Pelissier).

degeneration of the neuroglia and for that reason I wish to point out some facts that may clear a situation now in some confusion. It is not yet proved that the mucocitic degeneration of the oligodendroglia leads to the formation of the so-called "mucocite" which corresponds to the grapelike area. In my paper on the grapelike areas I have shown in detail that these areas are not the result of conglomerate oligodendroglia cells undergoing mucoid degeneration. I have pointed out how mucine may surround neuroglia nuclei and give the impression of a cellular unit. The mucine may even surround some of the nerve cells in the perineuronal spaces and simulate a cell body.

If, then, neuroglia cells containing mucine are found in the vicinity of or immediately surrounding the grapelike areas, it does not prove that the area is the result of the degeneration of these cells, although it may indicate that the swelling of the oligodendroglia is a concomitant phenomenon.

It is also important to note that, while the acute swelling of the oligodendroglia as described by Penfield and Cone is detectable in frozen sections, the "mucocite" of Grynfeltt and Pelissier, which corresponds to the grapelike area of Buscaino, is not seen at all in frozen sections.

The absence of true "mucocites" or grapelike areas from frozen sections is a well established fact, admitted even by those who favor the pathologic origin of these lesions. On the other hand, Buscaino himself now acknowledges that the action of alcohol is essential to the appearance of the grapelike area. Nothing of this kind is necessary to detect the acute swelling of the oligodendroglia, which is demonstrable in frozen sections and does not require the use of any sensitizer. This simple but important fact clearly indicates a definite difference between the two conditions. Were these conditions the same, one would expect the clusters (grapelike areas or "mucocite") to be as readily demonstrable as the acute swelling of the oligodendroglia. Penfield and Cone in their numerous experiments have not mentioned the appearance of such conglomerate clusters. They speak only of ruptured cell membrane and the naked appearance of the nuclei, but no grapelike clusters are reported as an end-result of the process.

Another important consideration is that acute swelling of the neuroglia has not been reported in normal brains as have the grapelike areas or "mucocites." If the acute swelling of the oligodendroglia represents an early stage of the grapelike formation, one would expect its presence in the normal tissue in which grapelike areas are found.

The nuclear reaction also seems to be different in the acute swelling and in the "mucocites." The nuclear changes occurring in acute swelling of the oligodendroglia are reported to be of the nature of a progressive shrinking and pyknosis. In the grapelike areas, however, I have pointed out the absence of striking changes in the nuclei embedded in the formation and I have insisted on the fact that if the area is to be considered the result of an agglomeration of degenerated neuroglia cells, one should find the majority of the nuclei in a far advanced state of degeneration.

As already indicated, Buscaino himself no longer holds the view that the grapelike clusters are the result of morphologic lesions of the nerve elements and admits that they are the expression of histochemical changes of the nerve tissue (i. e., the intercellular substance, the myelin sheaths or other substances) and that secondary signs of reaction may be seen in some of the parenchymatous elements (nerve

cells, neuroglia cells or even axons) in the vicinity of the areas. This view is not in accord with that which holds the grapelike areas to be an expression of an extreme swelling of neuroglia elements.

In the particular disease which has been investigated by Bailey and Schaltenbrand (encephalitis periaxialis diffusa), there is a large amount of free material found in degenerated areas which takes the stains like mucin. Such material has been found by other authors in various diseases and I may especially mention Lhermitte, Kraus and Bertillon [16] who found a mucinoid substance in a case of epidemic encephalitis. These authors did not find nuclei in the mucinoid masses and they objected to the use of the name mucocite to describe free material with no cellular structure. Bailey and Schaltenbrand encountered a large number of these free bodies, and in three cases of encephalitis periaxialis diffusa that I have studied a very large number were present in wide distribution. I must add, however, that besides the free bodies I also found numerous cells whose contents showed the same staining properties as the free mucine bodies. These cells are apparently of the same nature as those that Bailey and Schaltenbrand described in their case as undergoing a process of mucocitic degeneration.

Two questions arise here: 1. Are these cells oligodendroglia cells? 2. Is the mucin present in their bodies the expression of a degeneration or is it the result of scavenging or of an osmotic change?

It has not been established that the cells in which the mucin substance is present in cases of encephalitis periaxialis diffusa are oligodendroglia cells. I do not deny the possibility that, here and there, oligodendroglia cells may be encountered in which mucine is present, but according to my observations the majority of the cells present in the areas of degeneration in cases of encephalitis periaxialis diffusa in which mucine is found are the so-called gitter cells or scavenger cells whose origin is still a debated question. I personally believe that their origin is double and that microglia as well as astrocytes participate in their formation. This view is not entirely accepted and many authors, among whom are del Rio-Hortega, Penfield, Cone, Globus and Bailey, deny that astrocytes participate in their formation and believe that only microglia cells of mesodermic origin transform into scavenger cells. Some other authors have recently arrived at a compromise view (Spatz and Metz) i. e., that although the astrocytes participate to the formation of gitter cells they do not form mobile ones (mobile Abbauzellen or Abraümzellen).

16. Lhermitte, J.; Kraus, W., and Bertillon, F.: Mucine-like Bodies in the Central Nervous System in Epidemic Encephalitis, Arch. Neurol & Psychiat. **12**:620 (Dec.) 1924.

Aside from this debate, no investigations have been carried out with regard to the transformation of the oligodendroglia cells into gitter cells. The only mention of such a possibility I have found is in the work of Timmer, reviewed by Mrs. Junius Winkler in the *Zentralblatt für die gesamte Neurologie,* in which a statement was made concerning the transformation of oligodendroglia cells into gitter cells.

It must be admitted that the round cells containing mucine scattered in the degenerated areas of the encephalitic disease are largely transformed astrocytes, microglia and probably oligodendroglia. I have seen, however, collections of true gitter cells which at times assume a grapelike arrangement. These collections are definite in some of my slides, but I feel that they should not be confused with the grapelike areas of Buscaino or the "mucocites" of Grynfeltt. They are due to the collection of numerous gitter cells, and they may be seen in embedded material as well as in frozen sections. Since one is dealing here with scavenger cells, the presence of mucine may indicate merely the inclusion of mucinoid products of disintegration which are also to be found outside the gitter cells.

These considerations would lead one to believe that the presence of oligodendroglia cells showing a certain amount of mucine in their cytoplasm is not presumptive of a mucinoid degeneration of the cell or that the swelling of the oligodendroglia is identical with the grapelike bodies. Moreover, osmotic changes might result in the penetration of mucine into the oligodendroglia cells even in the absence of a phagocytic action on the part of these cells.

I admit that oligodendroglia cells may show mucine in their bodies, but I object to its identification with the so-called "mucocites" or grapelike areas. The mucinoid material in a pathologic process may represent one stage of the transformation of the disintegrating materials which result from the breaking down of lipoid or protein substances (presumably from the myelin sheaths) and its inclusion in neuroglia cells may merely be an expression of the scavenging process.

Bailey and Schaltenbrand described the presence of mucine in swollen oligodendroglia cells, a fact that had already been recorded by Pelissier, but they did not give data to establish the identity of the acute swelling of the oligodendroglia cells with the typical "mucocite" or the grapelike formation. They did not demonstrate transitory phases between the swelling and the characteristic grapelike areas of disintegration.

In their conclusions, these two authors apparently accepted the pathologic conception of the grapelike areas. This question is much too complicated at present to be solved by such fragmentary data as the presence of mucine in the oligodendroglia cells. An explanation must be found of the absence of grapelike areas in frozen sections in

contrast to the presence of swollen oligodendroglia cells there before the conception of the identity of these two processes is acceptable.

I think, therefore, that further investigations are necessary before identifying the acute swelling of the oligodendroglia with the grapelike areas of disintegration. The acceptance of such a conclusion before the comprehensive demonstration of intermediary stages might easily lead to confusion and prevent free investigation and discussion of two processes which, while possibly concomitant, are not as yet demonstrably the same.

News and Comment

NINTH ANNUAL MEETING OF THE ASSOCIATION FOR RESEARCH IN NERVOUS AND MENTAL DISEASE

The ninth annual meeting of this association will be held at the Hotel Commodore, Forty-Second Street and Lexington Avenue, New York, on Thursday and Friday, Dec. 27 and 28, 1928. The subject to be discussed is "The Vegetative Nervous System."

The sessions are held on the morning and afternoon of each day, the morning sessions beginning at 9:30 and the afternoon sessions at 2:30.

TENTATIVE PROGRAM

A. Historical Retrospect of the Vegetative Nervous System

B. Anatomy (Gross and Histologic)

1. Peripheral Distribution of Sympathetic and Visceral Afferent Fibers via the Communicating Rami and Spinal Nerves.
   Dr. Albert Kuntz, St. Louis.
2. Central Representation of the Sympathetic.
   Dr. W. B. Cannon, and co-workers, Boston.
3. Autonomic Nuclei of the Diencephalon, Brain Stem and Spinal Cord.
   Dr. E. F. Malone, Cincinnati.
4. Sympathetic Cells in Mid-Brain and Higher: Correlation as to Function.
   Dr. E. F. Malone, Cincinnati.
5. The Divisions of the Vegetative Nervous System. (Probably published and not read.)
6. Specific Ganglia and Plexuses of Visceral Organs. (Probably published and not read.)
7. Sympathetic Innervation of the Muscle Spindle.
   Dr. Marion H. Loeb, Baltimore.
8. Three Types of Fibers Going to Skeletal Muscles and Their Blood Vessels.
   Dr. S. W. Ranson and Dr. Hinsey, St. Louis.
9. Histology of Tuber Cinereum. Dr. E. F. Malone, Cincinnati.

B-1. Development of the Sympathetic. Dr. A. Kuntz, St. Louis.

C. Physiology

1. Sympathetic Nervous System in Relation to the Internal Secretions.
   Dr. W. B. Cannon and co-workers, Boston.
2. Sympathetic in Relation to Muscular Functions.
   Dr. W. B. Cannon and co-workers, Boston.
3. The Influence of the Vegetative Nervous System on the Capillary Circulation.
   Dr. J. Hamilton Crawford, Pontiac, Mich.

4. The Diencephalon in Relation to Visceral Functions.
G. Carl Huber and Elizabeth C. Crosby, Ann Arbor, Mich.

D. Pathology: Experimental

1. Histopathology of Cerebral Vessels; Presence of Sympathetic Fibers.
Dr. G. B. Hassin, Chicago.

2. Histopathology of the Sympathetic; Experimental in Character.
Dr. S. W. Ranson, St. Louis.

3. Dispensability of the Sympathetic Nervous System.
Dr. W. B. Cannon and co-workers, Boston.

4. The Rôle of the Sympathetic in Painful Affections of the Face.
Dr. Max M. Peet, Ann Arbor, Mich.

5. Regeneration of Sympathetic Nerve Fibers.
Dr. Ferdinand C. Lee, Baltimore.

6. Sympathetic Dysfunction in Lesions of the Nervous System.
Dr. Richard M. Brickner, New York.

7. Mechanism of Pain in Angina Pectoris and Lesions of the Peripheral Vascular System.
Dr. Wilder Penfield, New York.

8. Relation of Disturbances in the Vegetative Nervous System to Thoracic or Visceral Disease.
Dr. F. M. Pottenger, Monrovia.

9. Vagus Nerve Activity; Animal Experimentation.
Dr. Walter Hughson, Baltimore.

10. Parkinson's Disease.
Dr. Leslie B. Hohman, Baltimore.

11. Relation of the Vegetative Nervous System to Hyperthyroidism.
Dr. George W. Crile, Cleveland.

E. Pharmacology

1. Parathyroid Influence on the Vegetative Nervous System.
Dr. J. B. Collip, Montreal.

2. A Study of the Sweating Reaction Induced by Administration of Pilocarpine in Diseases of the Spinal Cord with Particular Reference to Its Use as an Aid in Localizing the Segmental Level of Spinal Cord Tumors.
Dr. C. B. Craig, New York.

F. Psychology

1. Relation of the Vegetative Nervous System to the Emotions.
Dr. W. B. Cannon and co-workers, Boston.

2. A Study of the Reaction of Adrenalin, Pilocarpine and Atropine on Psychoneurotic and Prepsychotic Patients.
Dr. David C. Wilson, Clifton Springs.

G. Syndromes of the Vegetative Nervous System

1. Reactions in the Autonomic Nerve Mechanism Caused by Sensitiveness to Heat and Cold.
Dr. W. W. Duke, Kansas City.

2. Autonomic Imbalance with Its Symptomatology.
Dr. Leo Kessel, New York.

3. Vegetative Neuroses, Especially Feer's Disease; Acrodynia.
Dr. A. S. Warthin, Ann Arbor, Mich.

4. Some of the Common Sympathetic Reflexes.
Dr. C. A. Patten, Philadelphia.

H. Surgical Therapy

1. Histologic Work Done on Ganglia.
Dr. H. H. Kerr, Washington.

2. Sympathectomy in Angina Pectoris.
Dr. H. H. Kerr, Washington.

3. Physiologic Effects Produced by Resection of the Thoracic Sympathetic Trunk and Removal of the Two Upper Ganglia.
Dr. George E. Brown and
Dr. Alfred W. Adson, Rochester, Minn.

4. Treatment of Anginal Pains with Paravertebral Injections.
Dr. James C. White, Boston.

5. Periarterial Sympathectomy in Raynaud's Disease.
Dr. George C. Muller, Philadelphia.

A CLASSIFICATION OF NEUROLOGIC, PSYCHIATRIC AND ENDOCRINOLOGIC DISORDERS

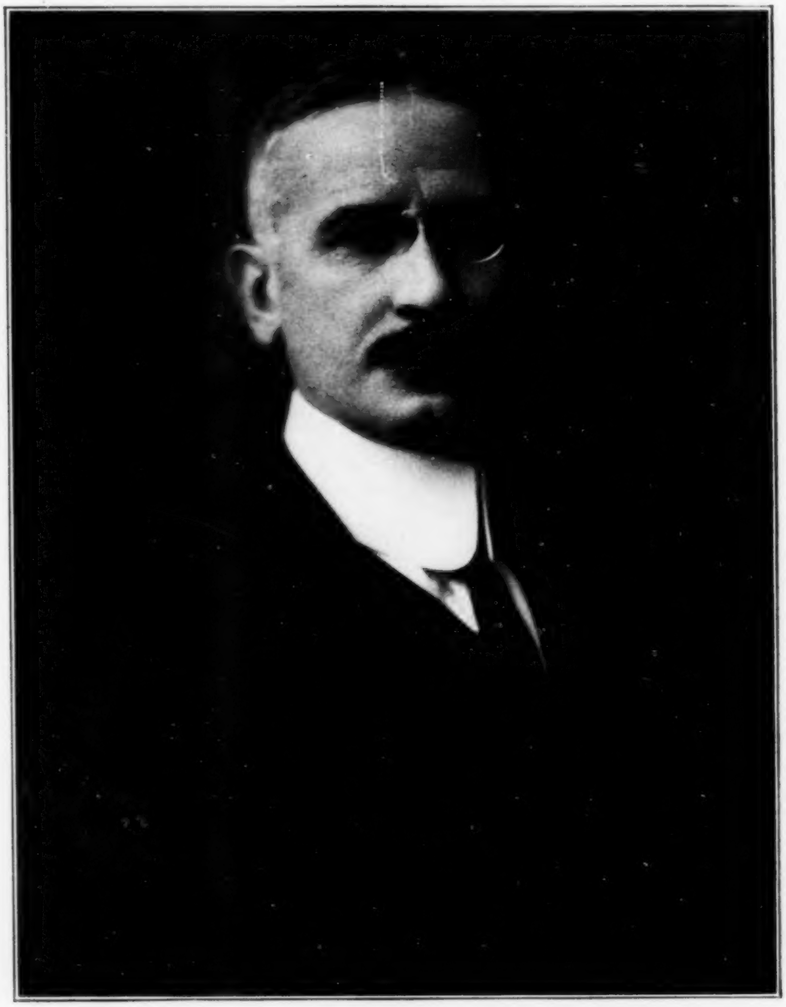
Prepared Under the Direction of the Committee of Classification of the American Neurological Association

For a long time neuropsychiatrists have felt the need of an up-to-date classification. As it is, each separate clinic and hospital has its own classification. To say that none of them has been satisfactory is merely stating an obvious fact. Increasing knowledge of the pathology of striatal disorders alone has added largely to the nomenclature. Endocrine disorders have also created the necessity for new names.

A committee representing neurologists from all over the country has prepared a classification of neurologic and psychiatric conditions. This classification is the result of a number of years of work, and at least has the merit of being up to date. It has already been adopted in the leading neuropsychiatric clinics in this country, but it is hoped that it will be adopted in all neuropsychiatric clinics and hospitals.

The neurologic classification is entirely new and up to date. The psychiatric classification is that adopted by the American Psychiatric Association some years ago. A revision of this new classification will probably be necessary in from five to ten years. It is urged that information concerning errors and additional material be sent to the secretary.

Copies of this classification can be obtained from the secretary, Dr. Henry Alsop Riley, 870 Madison Ave., New York, at $2.50 per copy or $2 when more than five copies are ordered. It is necessary to make a charge, for the American Neurological Association has been to considerable expense in the preparation and publication of the volume.



JOSEPH WILLIAM COURTNEY, M.D.
1868-1928

Obituary

JOSEPH WILLIAM COURTNEY, M.D.

1868-1928

After a brief illness of pneumonia, Dr. Joseph W. Courtney died at his home in Boston, on June 6. Dr. Courtney was born in Cambridge, Mass., Aug. 9, 1868, the son of William and Mary J. Courtney. His preparation for college was at the Latin School of his native city. He was a member of the Harvard class of 1890 and entered the Harvard Medical School, from which he was graduated in 1893. He lived and practiced in Boston throughout his life.

During his college course, he took particular interest in Romance languages and there laid the foundation for the really extraordinary knowledge of French which he found so great a source of satisfaction in later life. Early in his medical work, his attention was directed toward neurology, and he took opportunity while still an undergraduate to act as volunteer assistant both at the Boston City Hospital and at the Boston Children's Hospital. Soon after leaving the medical school, he received an appointment on the neurologic staff of the Boston City Hospital, at that time under the direction of three distinguished neurologists, Dr. Morton Prince, Dr. William N. Bullard and Dr. Philip Coombs Knapp. He was also associated at this clinic with Dr. John J. Thomas, who later became its chief of service. For many years, up to 1900, Dr. Courtney worked faithfully at this clinic, and finally resigned to take the position of physician-in-chief of the department of mental and nervous diseases at the Carney Hospital in South Boston, from which post he resigned in 1919. From this time until his death, he did not have an active official connection with hospitals, but nevertheless was a frequent visitor at the clinics and maintained an unfailing interest in medical progress. He retained a position on the consulting staffs of the Newton Hospital and of the Cambridge City Hospital. At one time he taught at the Boston Polyclinic and also in the Harvard Graduate School of Medicine, in which he served first as a lecturer and later, during the years from 1912 to 1920, as an associate in neurology. He was a member of many medical societies, among the more important being the American Medical Association, the American Neurological Association, of which he was vice president in 1913, the American Psychopathological Association, the New England Psychiatric Society, the Massachusetts Medical Society and the Boston Society of Psychiatry and Neurology. He served as president of the last mentioned society,

following a number of years of efficient service as secretary. He regarded as a particular distinction, and rightly, a correspondence membership in the Société de Neurologie de Paris. The Boston Medical History Club was one of his chief interests, to which he contributed a number of valuable papers chiefly concerning certain French worthies. He was an early member of a local society of distinction known as the Roxbury Clinical Record Club. He was likewise a member of the Author's Club of London and of the Papyrus and the Harvard Clubs of Boston.

As may be said of an increasing number of medical men, Dr. Courtney's interests extended far beyond the limits of his strictly medical work. He had a well developed and critical artistic sense which led him, in his spare moments, to take up etching; this ability he developed to a considerable degree of excellence. He was a collector of rare books and was fond of fine bindings. Perhaps his chief hobby was the accumulation of autographs and autographed letters of distinguished persons; of these he had a large number. Finally, he was a voluminous reader, particularly of the French classics. He was fond also of expressing his ideas on many subjects both in prose and in verse, often in an amusingly satiric vein, with which he frequently entertained his friends at medical meetings or on other occasions. One of the best of these skits was an entertaining paper of genuine humor entitled "Dr. Watson and Mr. Holmes; or the Worm That Turned," in which he transposed the characters of Sherlock Holmes and Dr. Watson, making the astute detective the foil of the dull-witted Watson. Among his poetic efforts, a reply to Kipling's "If" is a remarkable bit of verse. Although much of his interest lay in these outlying fields, he contributed his share of medical papers, all of which were written with extreme care and precision of expression not often met in contemporary medical writing. His published papers covered a wide range of subjects, both in the structural and in the so-called functional field of neurology. Many of these papers were case reports, presented with characteristic thoroughness, from which he always drew a valuable, and often an original, lesson. He enjoyed writing also on more speculative themes, as illustrated, for example, by his papers on "The Rôle of the Imaginative Faculty in Medicine," and "The Journalistic Doctor."

He was much interested in the psychoneuroses and had pronounced opinions regarding their genesis; he was strongly opposed to the freudian interpretation and found in it ample scope for the exercise of his satiric pen. His attitude was rather pessimistic regarding the possibility of treatment for functional disorders, and heredity meant much to him as an explanation of their existence. He felt, in almost a fatalistic way, that one could not escape from the handicaps with which one was born. Therefore, he was, in general, out of sympathy with the more optimistic environmental school, and on various occasions

took vigorous issue with the teachings of the newer psychologic point of view. His convictions were strong and were always defended with courage and skill.

Tempermentally, he was shy and distrustful of himself, which, as is so often the case, he concealed from the unobservant. Like all such persons, he was grateful for recognition or praise to an extreme degree and was equally sensitive to criticism or disapproval. As a natural result of this hypersensitiveness, he lived much within himself. He was not a regular attendant at medical meetings and did not take an active part in discussions, but when he did find himself on his feet, he spoke incisively and to the point, expressing himself in peculiarly well chosen phraseology. He prided himself on his use of English and with reason. His style was possibly a little pedantic at times but never slovenly or careless and often extremely forceful. He was doubtless much influenced by his devotion to the French and their literature. He spoke and wrote this difficult language with facility, and published several papers in French journals. His use of satire, in which he excelled, was presumably one result of this Gallic influence.

As a neurologist, Dr. Courtney stood high among his fellows. If he had not been of so shy and sensitive a disposition, he doubtless would have been even more widely known, but he always found it difficult to assert himself, and his ability, lacking a proper stimulus, often remained undiscovered. For a considerable period during the active years of his practice, he was much sought as an expert in medicolegal cases and established an enviable reputation as a witness. His testimony, given without circumlocution or unnecessary detail, made a definite appeal to the court, but to his friends he confided that this legal work never ceased to be an ordeal. During the later years of his life he made several trips to Europe, from which he derived the greatest satisfaction, especially in his first-hand contact with the French. He enjoyed also a sojourn in Geneva, on the occasion of the sixth meeting of the International Congress of the History of Medicine in 1926, at which he read a paper on "Benjamin Waterhouse, American Pioneer."

He was scholarly in his tastes, warm in his friendships and versatile in his accomplishments—an unusual and gifted man.

E. W. Taylor.

Abstracts from Current Literature

Frontal Pole Tumors. Takagi Ikutaro, Arb. a. d. neurol. Inst. a. d. Wien. Univ. **29**:280, 1927.

This work is concerned merely with examinations of tumors of the frontal pole, which involves only the anterior end of the three frontal convolutions, or, according to Brodmann's designation, the anterior parts of areas 9, 10 and 11. Following are a few pertinent cases cited from the literature:

In Byrom Bramwell's case, there were two adjacent tumors in the frontal lobe. One involved areas 9 to 11 and the other 46 of Brodmann and extended posteriorly toward the motor region. The symptoms were headache, vomiting, papilledema, weakness, a tendency to fall backward, diplopia, slight exaggeration of the tendon reflexes, paralysis of the left rectus externus and some nystagmus; there were no psychic or speech disturbances. There were pains and paresthesias of the left side of the face and body and the left side of the roof of the mouth. Later, twitchings of the right hand and jacksonian epilepsy developed. Autopsy revealed two sarcomatous tumors in the left frontal lobe, one in areas 10 and 11, and the other in area 46.

Serog describes a tumor which involved areas 8, 9, 10 and 46. Prominent symptoms were epileptiform attacks, psychic disturbances of a paralytic nature, weakness of the left side of the face, left ankle clonus, and a staggering gait with a tendency to fall toward the right side. Later, ataxia of the right leg appeared.

Two cases of P. Schuster are important in view of the question as to whether akinetic-hypertonic manifestations with tremor are associated with tumors in the frontal lobes or whether they are dependent on destruction in the basal ganglia. The first case was that of a patient presenting the characteristic symptoms of paralysis agitans who had an endothelioma occupying areas 10 and 11 on the left side. The second case was that of a patient with the clinical symptoms of paralysis agitans who had an endothelioma with its center near area 11 on the right side. The symptoms of paralysis agitans were explained by the finding of a small cyst in the putamen of one side and a small area of softening in the opposite putamen.

Hans Beyer presents several cases. The first was a tumor involving areas 11 and 16 and showed an exaggerated left knee jerk, normal abdominal reflexes and fainting attacks during which the head was turned toward the right and the left arm and leg were held in rigid extension. There was also a tendency on the part of the patient to fall backward. In the second case the tumor involved areas 9, 10, 11, and the adjacent part of 46 on the right side. The clinical manifestations, aside from the general symptoms, were epileptiform attacks, right proptosis, optic neuritis with visual disturbances, and tenderness on percussion in the right frontal region. The sense of smell was intact. The fourth patient had a tumor involving areas 10, 11 and 45 and probably 47. Aside from the general symptoms, the patient showed definite pyramidal signs on the right and there were no olfactory disturbances. After the successful removal of an echinococcus cyst there was diminution of smell on the left. In case 13 the patient presented serious ethical defects in addition to tumor symptoms. There also were right-sided facial paralysis, deviation of the tongue toward the right, tremor of the fingers, broad-based gait and a positive Romberg sign. Later, a severe psychosis developed. There was a tumor occupying the basal region on both sides including the entire gyri recti and the anterior parts of the gyri fornicati, i. e., areas 11 and 22 of Brodmann.

Before presenting his own cases the author emphasizes the fact that the location of a tumor does not permit absolute conclusions to be drawn concern-

ing the function of one part of the brain only, because there can be effects of a tumor on other parts of the brain, whether due to vascular changes or to pressure.

Case 1.—The symptoms were vertiginous attacks accompanied by unconsciousness, later generalized twitchings, severe headaches and a feeling of weakness in the legs. Roentgen rays showed destruction of the dorsum sellae and the posterior clinoid processes, indicating a lesion in the posterior cranial fossa. There was a papilledema of 3 diopters, and examination of the vestibular apparatus showed only a hyperirritability indicative of increased intracranial pressure. The attacks were periodic, with or without unconsciousness, and of a jacksonian nature, beginning in the left upper extremity. The cranial nerves showed diminution to high tones on the right and diminution of both corneal reflexes. There was also some weakness of the left arm with hypesthesia and increased tendon reflexes. There was also some dragging of the left foot. A diagnosis was made of tumor in the right arm center, probably more caudal than oral because of the sensory disturbances. The results of the autopsy were extremely surprising. There was an endothelioma in the right frontal pole involving the third frontal convolution, corresponding approximately to Brodmann's areas 10 and 11. The region around the tumor was carefully examined and the tissues surrounding area 10 showed two characteristics: (1) a diffuse edema with large vacuoles situated perivascularly and in the tissues themselves, and (2) marked dilatation of all the veins, especially on the surface of the gray substance. There was vacuolization around the ganglion cells, and the cells themselves showed changes in the arrangement of the tigroid substance. Axonal degeneration was also present. In the immediate neighborhood of the tumor where the edema was most marked, the nerve fibers were completely destroyed although ganglion cells still were present. There also were small hemorrhages. Areas 8 and 9 of the frontal lobe, which were some distance from the tumor, showed less edema, but the glial reaction was still definite. The contralateral side of the brain showed considerable swelling. Therefore, in this case there was a tumor on the right side completely involving areas 10 and 11 and practically sparing areas 8 and 9 of the frontal pole. The changes produced by the tumor were in fact "neighborhood changes" conditioned by budlike excrescences of the tumor growing into the neighboring tissues, and by edema, congestion and hemorrhage. There actually was an area far beyond the tumor which was completely destroyed and certainly must have had something to do with the clinical picture.

Case 2.—The patient gave a very meager history of a sudden onset of five weeks' duration, of severe headache, vertigo, blindness in the left eye and marked diminution of the vision in the right. Examination showed the skull diffusely tender on percussion, some exophthalmos, left pupil larger than the right and sluggish light reaction. During the course of the examination the patient became confused. A tonic convulsion ensued during which the arms were drawn up under the chin and the legs held in tonic extension. The tendon reflexes were brisk and there was bilateral ankle clonus and Babinski sign. Breathing became stertorous and the patient died a short time later. Autopsy revealed an endothelioma the size of an apple at the pole of the left frontal lobe with compression and edema of the brain. Areas 9 and 10 and probably part of 22 were involved. The surrounding tissues on the unaffected as well as on the affected side showed a distinct edema which was more marked than in the first case. There was a diffuse glial reaction such as is seen following parenchymal injury. Therefore, not only an area actually occupied by the tumor was injured but the whole frontal lobe of the affected side as well as part of the unaffected side in the sense of an edema and subsequent glial reaction.

Case 3.—This case is noteworthy because of its short duration. Three weeks before admission the patient complained of headache, vomiting and uncertain gait. There was tenderness on percussion over the right supra-

orbital region, deviation of the tongue to the left, and left facial palsy. Abdominal reflexes were absent on the left; there was complete akinesis of the left arm, and the right pupil was dilated and inactive to light. There was marked bilateral papilledema with hemorrhage in the left fundus. The patient died eight days after admission in a state of total confusion. Autopsy revealed a sarcoma involving areas 9, 46, 8 and 22 and hemorrhagic processes extending far in a caudal direction. The tumor was infiltrating in character and followed especially the blood vessels.

Case 4.—This illness began with a typical jacksonian fit starting in the right leg. Six years later there was beginning visual impairment and the fits were no longer typically jacksonian but the patient's knees would give way and she would sit on the floor five or six minutes and then get up without losing consciousness. There was not any headache or vomiting, but the right arm twitched. A few months later the vision became worse, and the patient had diplopia, amenorrhea and loss of weight. Examination revealed tenderness on percussion of the skull, left superior rectus palsy, marked diminution of hearing, tenderness on pressure over the left supraorbital region, horizontal nystagmus, left more than right, lid tremor, right facial weakness, diminution of both corneal reflexes, anosmia on the left, fine tremor of the hand, right more than left, hypalgesia on the right side of the body, right Babinski sign and marked bilateral papilledema. After several fainting spells, the patient died five months later and autopsy revealed a glioma involving essentially areas 8, 9, 46 and part of 6 on the left side. It was surrounded by a malacia in all directions. Part of the tumor grew along the corpus callosum across the midline but was confined to it on the right side. Only the softening which surrounded the tumor reached over to the opposite frontal lobe and destroyed there area 23 and part of 8. The tissues adjacent to the tumor were for the most part hyperemic. Here and there one saw small hemorrhagic areas with marked edema and softening. The edema decreased caudally and in the parietal lobe was only minimal. As in the earlier cases, the tigroid substance in the ganglion cells was disarranged.

Case 5.—A girl, aged 16, had had frontal headaches of one year's duration accompanied by tinnitus aurium. Two months later bilateral papilledema developed followed by diplopia in three months. Because of weakness and vertigo, the patient was unable to walk. Later, paresthesia developed in the inferior branch of the right trigeminus, right side of the tongue and right forearm. Objective examination showed that the skull was not tender; there was abducens palsy; corneal reflexes were present; the tendon reflexes were more brisk on the right than on the left. There was not any Babinski sign, ataxia or adiodokokinesis. Past pointing tests showed an outward deviation of the right hand, and caloric tests indicated a cerebellar tumor evidently pressing on the base of the brain. Later, both corneal reflexes were diminished, and adiodokokinesis and ataxia developed in the right arm. There was a staggering gait and a marked Romberg sign. This patient was operated on for cerebellar tumor and died of hemorrhage. Autopsy revealed a spongioblastoma occupying the left frontal pole in the region of the middle convolution occupying all of area 10 and the ventral side of 9 and dorsal part of 11. The tumor was infiltrating into the surrounding tissues and the meninges and there was considerable edema extending from areas 8 to 9. The nearer the tumor one looked, the more perivascular disintegration one found. There also was sclerosis of the ganglion cells.

The author attempts, from a review of his and the other cases presented, to enumerate symptoms which may be of assistance in the diagnosis of tumors of the frontal pole. First, he emphasizes the fact that in all cases headache was present. Vertigo occurred in one-third, and vomiting in about one half of the cases. Tenderness on percussion over the skull was frequently present, occasionally at the site of the tumor (one-half the cases). Papilledema was found in twelve of fourteen cases. The appearance of epileptiform fits, especially of the jacksonian type, is an important sign. They were present in

half the cases and occurred late in the disease, indicating that the pathologic process began orally and extended caudally. The late occurrence of the fits is about their only diagnostic value in frontal pole tumors since they also occur frequently with tumors in other parts of the brain.

In the author's cases psychic manifestations were not an important occurrence, and this is in contradistinction to what one ordinarily sees. No certain type of psychosis was found and all the psychic symptoms that did occur could be explained by cerebral pressure.

Labyrinthine irritability was present in two cases and in one case led the otologist to a diagnosis of cerebellar tumor.

Unilateral olfactory disturbances were infrequent (three of fourteen cases).

Paralytic symptoms of varying degree in one half of the body and reflex differences occurred rather frequently. Because of the basal location of most of the tumors, the face, tongue and upper arm were most frequently affected, indicating that the tumor had grown caudally and involved the lower part of the anterior central gyrus before ascending to the region of the leg.

A distinct aphasia, even in left-sided tumors, was not present.

Sensory disturbances were present in two cases in spite of the oral locations of the tumors.

The most confusing symptom is the ataxia. Cerebellar symptoms appeared in six of fourteen cases, and the author thinks they are due to an internal hydrocephalus. They are not so outstanding in frontal lesions as they are in true cerebellar lesions.

Occasionally one sees symptoms of involvement of the basal ganglia such as tremor of the hands or lids, symptoms of paralysis agitans, coarse tremor of one arm or hypertonicity in a leg. These phenomena are conditioned either by pressure or by actual involvement of the basal ganglia by the tumor.

To formulate a clinical syndrome for frontal pole tumors one must consider the existence of a unilateral olfactory disturbance together with contralateral manifestations on involvement of the cranial nerves or of mild hemiplegic signs such as reflex differences or weakness of one arm or leg. A strictly localizing diagnosis cannot be made on the basis of the anatomy of the parts affected since the pathologic processes are rarely localized in the strict sense of the word. This is shown by the examination of the tissues surrounding the tumor and of the opposite side.

This work was intended to answer two questions. 1. Can tumors of the frontal pole be diagnosed? 2. Can these tumors produce general cerebral damage as well as local?

The first question must answered in the negative. Only in the rarest instances can one diagnose frontal pole tumors, and then only when the characteristic syndrome already mentioned stands out above the general symptoms.

The second question can be answered by the statement that the injury by direct growth of the tumor, hemorrhage and softening is considerable, and that aside from this we must reckon with a homolateral and contralateral edema and corresponding congestion when evaluating the symptoms of such a tumor. Only in this way can one understand how parietal lobe symptoms can occur in tumors of the frontal pole.

KAMMAN, St. Paul.

OPERATIVE TECHNIC IN CASES OF BRAIN TUMOR. L. PUUSEPP, Fol. Neurop. Eston. **6**:127, 1926.

This article is an introduction to a series dealing with tumors of the brain which will be published later in monograph form. It is a recital of the technic employed by Puusepp as the result of more than 400 operations in such cases. Some of these details seem to be well worth consideration by neurosurgeons of the Western world.

The patient usually lies on his side, sometimes on his back or front, but he no longer sits up. The prone position is objectionable in case there is bleeding,

because the blood is likely to gravitate to the base of the skull and disturb the pulse and respiration. In two cases, when the patient was changed from the prone to the lateral posture, these embarrassments disappeared. An especially heated table does not seem to be necessary. In case of free and diffuse bleeding, the upper portion of the body may be raised. In order to avoid cooling of the exposed brain, the operating room is kept at a temperature between 68 and 70 F. During the revolution in Petrograd, the operations often had to be carried out in rooms at about 50 F. At this time almost all cranial operations were accompanied by marked disturbances in pulse and respiration.

Craniocerebral topography occupies the next section, and several methods are described, both from measurements and with apparatus. The author prefers Chipault's method, in which the median sagittal line from the nasion to the external occipital protuberance is divided into one hundred parts and the rolandic point found at 70. The other base is the spine on the zygoma between the zygomatico-frontal suture and the upper limb of the zygoma. From this point, lines are drawn corresponding to the sylvian and the sinus regions, and each of these is divided into ten parts. The rolandic fissure underlies the line developed from 70 on the median sagittal line and 3 on the sylvian line. The author goes into considerable detail in describing these methods, because he considers small openings with careful localization better than general localization with a large osteoplastic flap.

Anesthesia is usually general, chloroform often being used, and is preceded by hypodermic injection of morphine and strychnine. Local anesthesia is hard on the patient's nerves and is carried out with 1 per cent procaine and epinephrine. Anesthesia is maintained at a deep level until the dura is opened. The author does not mention any bad effects on the substance of the brain from the use of ether.

The skin is disinfected with iodine, following wet compresses with 0.1 per cent sublimate solution. After the location of the opening is decided on but before the scalp is incised, the author passes a number of interrupted catgut sutures around the site of operation, taking in the galea and drawing them tight, so that he operates in practically a bloodless field. This is more satisfactory than the running continuous stitch used by Heidenhain because it permits an extension of the incision by cutting only one of the strands. At the close of the operation every second suture is left and is removed twenty-four hours later. This part of the operation is quickly performed, and leaves the field practically bloodless.

The removal of the bone is carried out by means of a burr and Dahlgren's bone cutter. Wax is used to arrest bleeding from the bone and seems to be absorbed quickly. Short spurs on the bone should be cut away with rongeur forceps. The flap is broken back, and the condition of the dura is examined. The presence of a superficial tumor is recognized by the marked developement of the blood vessels in a small area. A white dura signifies compression and reactive thickening. If the dura is tense, ventricular puncture is performed.

It seems better to complete the operation at one sitting if possible, but in some cases the method of physiologic enucleation suggested by the author in 1913 may be useful.

The dura is opened by a horseshoe incision somewhat smaller than the bone incision. This may be done by probe-pointed scissors or by means of a cutting sound with a sheath. The arachnoid is often removed with this. When the dura is reflected, a tumor is easily recognized if superficial. If it lies beneath the cortex, the visible portions will be pale and the convolutions flattened. Sometimes there is so much pressure that rupture of the cortex occurs, and the tumor is presented in the opening. The tumor-bearing area is often softer to the palpating hand, and puncture will often aid in the decision. If the tumor springs from the membranes, it is best removed with the fingers.

Physiologic enucleation applies to those tumors situated deep in the brain. In such instances the procedure is to halt the operation when the dura has been

opened and then to remove the bone and suture the skin in place. Two weeks later, on reopening the incision, the tumor is often found superficial and easily removed. The brain seems to get rid of the foreign body in the direction of least resistance.

Particles of tissue removed by trocar can often be detected as tumor tissue, and such a trocar is used instead of a blunt needle.

After removal of the tumor, the hemorrhage is carefully arrested. Sometimes the whole cavity is packed and the dura sewed over it, but it seems useless to attempt to fill the defect with fat or muscle. In cases of large tumors of the brain, the bone flap is removed.

If packing is removed in twenty-four hours and the skin sewed up completely, these cutaneous sutures are removed in eight or nine days. It seems advisable to remove a certain amount of bone before the closing because of the acute swelling of the brain that takes place during the days following operation. Since Puusepp has been using this method, his mortality has fallen from 12 to 3 per cent, and he states that the reduction can be explained only on the grounds of this change. The decompression opening probably acts as a safety valve, compensating for the swelling of the injured brain.

In cases of malignant tumor, such a bone defect is advisable and postpones the recurrence of general symptoms. Repeated operations can also be performed through the same incision, without much difficulty, and under local anesthesia.

In order to limit the size of a trephine opening, the bone may be entirely removed over an area of from 5 to 7 cm., and osteoplastic flaps then built up from the side. In operations near the longitudinal sinus, it is often well to split the dura, and even then the sinus is sometimes injured. In these cases, the sinus must be sutured, and the attempt made to arrest bleeding by passing silk sutures impregnated with hot wax. This often fails on account of the multitude and size of pacchionian bodies and veins, and the sinus must often be ligated in two places. This procedure is useful in exposing tumors of the corpus callosum. Such ligation of the sinus in its anterior two thirds does not cause serious complications, but it should be done only when absolutely necessary. If the sinus is injured in the beginning of the operation, a lateral suture is often effective.

Palliative decompression is being carried out less and less often, but is still useful in certain cases. Puusepp carries this out in the location in which the symptoms suggest the presence of tumor, and not merely in the subtemporal region. In order to elicit focal symptoms, in case symptoms of general pressure are severe, the injection of hypertonic saline solution is utilized and often indicates a location for the decompression.

Postoperatively, the pulse and respiration are controlled if possible. Saline injections, either subcutaneously or intravenously, are forbidden on account of the danger of hemorrhage in the brain. In cases of occipital explorations, movement of the neck is prevented by a collar. A purgative is administered two days after the operation, and often reduces the postoperative intracranial pressure. The patient can get up in about three weeks. If hernia develops, it is well to puncture it and remove from 20 to 30 cc. of fluid. Such a puncture may be repeated two or three times when the patient complains of tightness. A rise in temperature to 100 F. is not to be regarded as serious since it denotes the general reaction to aseptic serous meningitis and disturbance in the circulation in the brain.

FREEMAN, Washington, D. C.

EXPERIMENTAL INVESTIGATIONS ON THE THERAPEUTIC VALUE OF INTRALUMBAR SERUM INJECTION. H. PETTE, Deutsche Ztschr. f. Nervenh. **96**:165 (March) 1927.

Treatment with intralumbar serum in some of the toxic infectious diseases had its conception in the idea that, by this method, specific antibodies may be brought more readily to the affected area than is possible through the general circulation. So far, the results of only a few investigations on the histologic

changes taking place in the central nervous system after this method of treatment have been reported. Hoff and Silberstein have reported an increase in cell count and globulin in the spinal fluid after injecting dogs with horse serum. Rohr found marked lymphocytosis in the fluid after injecting children suffering from chorea minor with homogenous serum. Pette's investigations were for the purpose of learning more about the character of the cerebrospinal fluid as well as the reactions taking place in the meninges and brain tissue after the injection of homogenous and heterogenous serums by the lumbar route. Rabbits were used for the experiments; the serum was inactivated for a half hour at 56 C. and then was bacteriologically tested. Up to 1 cc. of serum was injected, and only animals with a healthy central nervous system were used.

Eight animals received serum. Six of these received one injection and two received two injections (one fifteen days after the first injection; the other three days after). Three animals died soon after the first injection. Five animals received a single injection of human serum, four received two, one received three and two received four injections.

Soon after the injection, the spinal fluid became turbid. The degree of turbidity depended on the relative increase in the number of cells. This lasted about one or two days. The Pandy reaction was strongly positive during the first few hours after the injection and rapidly became negative even before the cells had disappeared completely. The same was true with the mastic curve.

The cell count fluctuated from 250 to 20,000 per cubic millimeter. The highest mark was found within the first day after injection. The author did not find a marked difference between the reaction after the injection of homogenous and that after heterogenous serum. The animals injected with human serum usually gave a stronger reaction, an increase in cells at times up to 20,000, but even in this group some showed an increase only to 450. Similar differences were also found in animals injected with homogenous serum; one rabbit gave a reaction of 14,000; another, of only 624 cells. Repeated injections did not give marked changes. For instance, one animal gave a reaction after the first injection of 1,240 cells and after the third injection of only 250, while another gave a reaction after the first injection of 250 and after the third of 2,496. The period during which there was an increase in the number of cells showed no regularity. One animal was not cell free until after twelve or thirteen days, while another was nearly cell free after a few days. There was not any relation between the degree of the reaction and the length of time in which the number of cells was increased. A strong reaction did not always retain a high cell count for a long period.

Clinically, the reaction showed itself in a suggestion of opisthotonous and a rise in temperature of from 0.5 to 1 C. during the first two days. The increase in the temperature was noted when the cell count was highest, which was often a few hours after the injection.

The larger number of cells were of small size and round; these appeared the earliest. Mixed with them were lymphocytes and leukocytes. The latter appeared in maximum number about twenty-four hours after the injection. They seldom formed more than 10 per cent of the total cells. After three days they decreased proportionately, so that they were seldom found after five days. The lymphocytes remained much longer; they increased and diminished more slowly. They formed about 8 per cent of the total count in the first twenty-four hours. After two or three days some large epitheloid cells appeared in small numbers.

All the tissues coming in contact with the serum showed a marked reaction within a few hours after the injection; in this the meninges and the blood vessels took part. Many adventitial cells were seen to pass from the vessel walls into the subarachnoid space. The reaction increased and reached its maximum in about twenty-four hours. The meninges at the base were more strongly affected. The ventricles showed a similar reaction. The convexity

of the brain showed less reaction and at times none at all. From a histologic study the author could not find any distinction in the reaction between the use of homogenous or heterogenous serum.

In those animals that had received several injections a glia reaction was found occasionally in the molecular layer and a slight lymphocytosis of the meninges at the base, especially near the chiasm. A few times the author found a mild glia reaction at the base, near the opticus. The reaction in the spinal cord was strongest at the medulla; from there down it rapidly diminished to normal. The author, although guardedly, sees a meningitis in this reaction, which he considers due to the irritation of the serum acting as a foreign body. This reaction remains as long as the irritation is present. He regards it, therefore, as an inflammatory process in the sense of Lubarsch, in which the tissue tends to bring into play all its defensive antibodies. The hyperemia in the meninges and in the neighboring tissues exerts, no doubt, a favorable influence on the tissue metabolism, stimulating the production of antibodies.

Clinically, the author found a similar reaction in the human organism. A number of postencephalitic patients were given intralumbar injections of autogenous serum. The author reports ten such cases. The reactions, he found, varied little from those in his experiments on rabbits.

BERNIS, Rochester, N. Y.

THE BLOOD SUPPLY OF AMMON'S HORN. JUSTIN UCHIMURA, Ztschr. f. d. ges. Neurol. u. Psychiat. **112**:1 (Jan.) 1928.

The question of sclerosis in Ammon's horn has recently been reopened by Spielmeyer. The presence of etiologic changes in Ammon's horn in epilepsy was discussed for a long time, but the view was abandoned, especially in view of the work by Bratz who found changes in Ammon's horn not only in epilepsy, but also in idiocy, general paralysis and other conditions associated with convulsions. Recently, Spielmeyer has found that the typical localized pathologic process in Ammon's horn may be caused by vascular diseases, as in tuberculous vascular disease, vascular syphilis, arteriosclerosis and in infectious diseases. He concludes that the change is due to circulatory disturbances, and that the changes produced in epileptic persons are due not to disease of the vessels, but to functional disturbanes in circulation — angiospasm with or without vasomotor paralysis. The pathologic changes in Ammon's horn take place in definite sites of election and are characterized by loss of ganglion cells and their replacement by glia cells, leading to the typical sclerosis. The site of election in the portion nearest the ventricle, the dorsal leaf being at times more affected and at other times the ventral. The end portion surrounded by the gyrus dentatus is as frequently implicated. One portion, however, usually escapes, no matter how long the clinical course or how marked the process elsewhere in Ammon's horn. This portion is in the dorsal leaf and has been called by Spielmeyer "the resisting portion." The granular layer of the fascia dentata is also resistive; the lesion is consequently localized.

There are two views as to why the changes occur in Ammon's horn. According to C. Vogt and D. Vogt, they are in the nature of a systemic disease and the differences in the vulnerability of the various portions is explained on the basis of differing physiochemical properties of the various parts. Spielmeyer explains the changes on the basis of circulatory disturbances within the cornu ammonis. To establish this, it is necessary to determine a relation between the vulnerability and the nourishment of the organ. This Uchimura attempts to do. His material consists of twenty-one cases, twelve without changes in Ammon's horn, and nine with the typical cell loss. In five cases, only one cornu ammonis was involved, so it was possible to compare the two sides. Serial sections were made of the region under consideration and appropriately stained.

The cornu ammonis, with the exception of a small part of the uncus, receives its blood supply from the posterior cerebral artery. It has two large arteries; one enters the brain substance either in the fissura hippocampi, which lies

between the gyrus hippocampi and the gyrus dentatus, or in the upper surface of the fascia dentata. If the vessel enters exactly through the fissura hippocampi, as is often the case, it runs wholly in the system between the gyri mentioned. If, however, the vessel enters from the upper surface of the gyrus dentatus, as occurs often, it first runs laterally along this gyrus, penetrates the granular layer and arrives at the septum between the gyrus hippocampi and the gyrus dentatus. At this point in most cases the main vessel divides into several branches without having previously given off branches. These main branches at the end of the vessel run to the pyramidal cell layer and supply a large part of the ventral leaf. A large branch may be given off to the resistive portion. Smaller vessels are also given off from the main vessel in the fissura hippocampi to the subicular region. The second vessel takes its origin dorsal to the first. It enters the brain substance always from the gyrus dentatus, and runs chiefly on this convolution. At first it runs wholly laterad, and when it reaches about the middle of the lateral half of the gyrus dentatus changes its course and bends dorsad. In addition to these two main branches, the cornu ammonis receives a few smaller vessels. Some of these come from the fissura hippocampi, others from the sulcus fimbriodentatus. One of the latter suppplies the fimbria and its surroundings, while another supplies the largest part of the resistive portion of Ammon's horn.

Sommer's sector in the cornu ammonis receives its blood supply chiefly from one artery which runs more or less the length of the medullary septum, and Uchimura emphasizes the fact that the supply is from one vessel and that collateral circulation is out of the question for this sector. On the other hand, the resistive portion, the small dorsal leaf, is richly supplied by several vessels which come to it from different directions. Uchimura's studies show that it is supplied, as a rule, by more than three, and by never less than two branches. This difference is demonstrated in pathologic sections in which the resistive portion is little involved in the process, while Sommer's sector is markedly degenerated. Between these two parts is a transition zone which as a rule, shows ischemic changes. The blood supply to these parts is not constant because the extent of Sommer's sector and of the resistive portion is not always the same. The long course of the vessel to Sommer's sector and the absence of collaterals makes this part especially valuable, and Spielmeyer thinks its position in the medullary system causes a disposition to circulatory disturbances. Uchimura supports this view by stating that this vessel, which is thin-walled, becomes thick-walled owing to the presence of pseudocalcified bodies when it enters the medullary septum.

The question arises why all epileptic persons do not show changes in the cornu ammonis. According to Baty, changes are present in this region in only 50 per cent of the cases. Uchimura says this percentage would be decidedly higher if the milder changes in this area were included in addition to sclerosis. He attributes the absence of results in certain cases to the variations in the blood supply.

Alpers, Philadelphia.

Children in General Practice: A Study Both of Temperament and of Disease. H. C. Cameron, Lancet **1**:1 (Jan. 7) 1928.

The study of the nervous child may be approached from many points of view. One may regard him as presenting a problem in management; one may concentrate attention on the bodily state, or one may view him from the standpoint of the biochemist and study his metabolism. The nervous child is more sensitive to the influence of those around him and in charge of him. To any mistake of management he responds with a maximal disturbance. The trivial disturbances of conduct or health, which at some time become manifest in all children, may be transitory or may be perpetuated because they are kept in the forefront of the child's consciousness by the too obvious concern and apprehension of the parents. Infantile misconduct may result from the desire to produce the maximal emotional response in the mother. Consequently, parents should

hide from children their power to disturb. A management which never ceases from attempts to control may arouse in the child antagonism and negativism. The mother must correct her too obvious disappointment in the child, in fact overcorrect her own attitude in order to restore the sensitive child's position to the normal.

The author can see no reason for not regarding enuresis as hysterical. All children, or most children, are physiologically hysterical if by that one means that they are prone to fall under the influence of any suggestion made by the grown-up people on whom they rely for support and protection. The child with enuresis is a hypersensitive child, to whom his infirmity is absolutely abhorrent. Not only does he care but he cares too much. Many children compensate by assuming an attitude of unconcern. With the sensitive child, too great stress on the occasional accident and too little on the growing control leads directly to the development of the disorder. To cure enuresis, the pessimism of the parents must be replaced by an all-embracing optimism.

Many children live on a metabolic curve or cycle. In many of the depressions of this curve gastro-intestinal symptoms appear in a dominating rôle, and sometimes one encounters periodic or cyclic vomiting. Energy, emotional and muscular, is derived from carbohydrates, only little reserve of which is stored in our bodies. Starvation, exertion and emotional excitement all deplete this reserve and force one to fall back on the second choice of supply of energy, the fats. The metabolism of fat is completed only in the presence of a sufficient supply of carbohydrate. In the absence of this, ketone bodies are formed. In the type of child under consideration, the stresses of life produce ketonuria and disturbance of acid-base balance. The nervous child has in general a high basal metabolic rate. His need for carbohydrate is high, and at the same time there is evidence that his powers of metabolizing fats are relatively low. The nervous child is more prone to develop ketonuria than his brothers, and the nervous symptoms become aggravated when the metabolic disturbance arises. Night terrors are frequently best controlled by the administration of dextrose at bedtime. The nervousness of these children may be compared to that of hypoglycemia, which is readily controlled by dextrose.

The most characteristic symptom of recurrent metabolic crises is the tonelessness of the skeletal muscles, the vasomotor muscles and perhaps of the intestinal muscles. This amyotonia may persist in part between the attacks. The child presents, in addition to this, pallor, proneness to fatigue, foul-smelling breath, yawning, persistent slight elevation of temperature, irregular action of the heart and inability to develop body fat. Many of these cases present slight pyrexia for weeks or months at a time. Sodium bicarbonate is often sufficient to control this fever. In the treatment of these children, it is important to preserve a proper carbohydrate-fat ratio so that the metabolism of the latter will be complete. Dextrose and soda may efficiently combat the tendency to ketonuria.

Petersen, Montreal.

Pure Word Deafness with Especial Consideration of Amusia. Robert Klein, Monatschr. f. Psychiat. u. Neurol. **64**:354 (Aug.) 1927.

The case report is: The patient, aged 51, had endocarditis which resulted in two strokes. The first stroke three years previously, had caused a transient aphasia of undetermined type. The second produced the picture of a subcortical sensory aphasia and left hemiplegia, which continued unchanged for one year. At the time of examination the patient showed almost complete word deafness with a corresponding loss of repetition. Spontaneous speech was normal except for iteration, a tendency to telegraphic style and some dysarthria. Reading, like spontaneous speech, was undisturbed except for iteration. Understanding of what was read was normal. Writing showed considerable paragraphia. Musical tones were usually appreciated as such, but there was a complete loss of musical appreciation and of music production.

The picture is that of pure word deafness. The spontaneous speech and writing were slightly affected. One expects recognition of music to be affected in such cases; as a matter of fact, it is usually so much affected that at best only different tones can be recognized as different. The interesting point in the case reported, however, was the complete loss of musical function — both appreciation and expression. In discussing the relations of speech and music, the author points out that for the average person, development of musical functions corresponds to the speech functions of a child just beginning to talk — of a child who can repeat spoken words and can understand some things, but who cannot formulate and produce anything for himself. Because of this primitive development of the musical function and its intimate connection with the perceptive side, about which all musical memory is developed, it can happen that a lesion capable of producing only a subcortical sensory aphasia on the speech side, without disturbance of inner speech, can produce on the musical side such gross disturbance of "inner music."

The anatomic basis of pure word deafness, or subcortical sensory aphasia, is still in dispute. Some hold to the Lichtheim schema, others to the view that bilateral lesions, or partial unilateral lesions of the first temporal region are responsible. As to the anatomic basis of amusia, Henschen holds that pure sensory amusia is always associated with a lesion of the left first temporal convolution, especially toward the temporal pole. But a study of the literature suggests that when not only tone appreciation but also tone memory is involved — that is, when there is complete sensory amusia, which will include disturbance or loss of music production, a disturbance of "inner music" — a bilateral lesion will be found. The differentiation of cases of tone recognition from those with this loss plus loss of tone memory is not difficult. The patient who has lost not only tone recognition but also musical memory can scarcely be brought to attempt to sing; this was true in the case recorded.

If one assumes a bilateral lesion for these cases of complete amusia, it must be a symmetrical lesion of both first temporal convolutions, and similarly one must assume a similar lesion as a basis for the pure word deafness in the case cited.

Selling, Portland, Ore.

Investigations on the Circulation of the Cerebrospinal Fluid by Means of Intravenous Injections of Fluorescein. Georg Schaltenbrand and Tracy Putnam, Deutsche Ztschr. f. Nervenh. **96**:123 (Feb.) 1927.

Schaltenbrand and Putnam conducted a series of experiments, using intravenous injections of fluorescein as an aid in studying the circulation of the cerebrospinal fluid. Their object was to learn more about the source of the fluid and to ascertain, if possible, whether it is to be considered a product of secretion or a transudation. The experiments were carried out on fifteen cats, one dog and one rabbit. After a certain part of the central nervous system was exposed, a 10 per cent solution of fluorescein (Schultz M 585 of the National Aniline and Chemical Company) was injected intravenously. The exposed part was then observed with a binocular microscope. This fluid is slightly hypertonic and has a freezing point of about —0.75 C. Immediately after the dye is injected, the skin and mucous membranes assume an intensive green color; saliva and tears become green. A few minutes later a green ring is observed in the anterior eye chamber, along the edge of the iris and, soon after, the entire anterior chamber is filled with the fluorescein fluid. The appearance of the dye in the cerebrospinal fluid follows. It reaches its maximum, in point of color, in about fifteen minutes. The muscles and connective tissues become deep green, while the dura is light green. The central nervous system, on the other hand, remains practically unchanged. Only after the injection of large doses of the dye, does the gray substance appear slightly greenish. The white substance remains unchanged. The choroid plexus, the stalk of the hypophysis and the connective tissue of the caudal part of the fourth ventricle assume a lively green color. The authors observed its effect on the cisterna magna, the convexity, the choroid plexus of the lateral ventricles and on the spinal cord.

In observing the cisterna magna after the injection of dye, Schaltenbrand and Putnam found that dye did not pass through the foramen of Magendie but only through the foramina of Luschka into the cisterna. On the convexity of the brain, the authors observed that the dye passed out from the arteries and somewhat later from the veins. Similarly, but in a lesser quantity, they found that this was true with the spinal cord. The greatest quantity of the dye was observed in the lateral ventricles; it appeared there soon after the injection.

From their observations, Schaltenbrand and Putnam came to the conclusion that fluorescein passes through the choroid plexus and through the arteries and veins of the subarachnoid space into the cerebrospinal fluid. The largest quantity passes through the choroid plexus, less through the arteries and still less through the veins. Fluorescein apparently exerts no special influence on the blood vessels. It passes through a membrane like water, salt solution, sugar, etc. The authors, therefore, think that their experiments support the view that the cerebrospinal fluid is a product of transudation, thus supporting the dialysis theory of Fremont-Smith (Arch. Neurol. & Psychiat. **17**:317 [March] 1927) and others.

Bernis, Rochester, N. Y.

The Use of Hypertonic Solutions in the Treatment of Increased Intracranial Pressure. W. Russell Brain, Brit. M. J. **1**:86 (Jan. 21) 1928.

Weed discovered that hypertonic solutions could be used to diminish increased intracranial pressure. By raising the osmotic tension of the blood, water is withdrawn from the brain. When used by mouth, the osmotic tension is raised by withdrawing water into the intestine. For intravenous administration, one can give from 70 to 100 cc. of a 15 per cent solution of sodium chloride up to a maximum of 100 cc. of 30 per cent solution. Some prefer dextrose, from which they claim more beneficial results. The maximum dose of this is 100 cc. of a 50 per cent solution. The injection should enter the vein slowly. For the oral method one gives 16 Gm. of sodium chloride in 2 Gm. capsules with 80 cc. of water or 3 ounces of a 50 per cent solution of magnesium sulphate. When mild continuous action is desired, one may employ repeated doses of magnesium sulphate, from 0.5 to 1 drachm. Rectal administration is, generally, the most useful way. For this one gives 6 ounces of a 50 per cent solution of magnesium sulphate slowly into the rectum at body temperature. To produce results, this must be retained for at least half an hour. Together with the administration of salines, the intake of water must be restricted. Magnesium sulphate should not be given intravenously, as it produces general anesthesia and respiratory paralysis.

This method of reducing intracranial pressure and so of aiding in resorption of exudate is of use in treatment for "persistent cerebral contusion" following injuries to the head. In this condition one has headache, nervousness, irritability, giddiness, anxiety and sometimes bradycardia. The local contusion produces edema which impairs circulation, forming a vicious circle. If all other measures fail, subtemporal decompression should be performed. In acute injuries to the head, hypertonic solutions are of great aid in reducing the edema, and intravenous dextrose would seem to be the best solution in this case. If the state of shock is profound, such treatment should not be used. The contraindications are low temperature and blood pressure and rapid or rising pulse rate. In tumor of the brain, three factors contribute to the rise in intracranial pressure: the tumor itself, its effect on intracranial circulation and a combination of the two, producing internal hydrocephalus. Hypertonic solutions reduce the formation and increase the absorption of cerebrospinal fluid and so temporarily relieve the hydrocephalus. This may aid in diagnosis by allowing a more satisfactory examination and may reduce intracranial pressure in emergencies long enough for an operation to be performed. In inoperable cases, it will act as a palliative.

Injection of fluid under pressure into the subarachnoid space leads to a rise in blood pressure and so in cerebral hemorrhage a vicious circle is produced and continued bleeding takes place. Venesection is a rational form of treatment, as it tends to reduce intracranial pressure, and hypertonic solutions have only a limited use in connection with it. Intravenous injection is contraindicated, as it tends to raise the blood pressure. It is doubtful whether rectal administration has any influence if the bleeding is still going on, but by lowering intracranial pressure when the bleeding has stopped it may be of value. Free purgation lowers the pressure in the same way. Other uses of hypertonic solutions are for postoperative treatment in cerebral abscess and for the relief of headache in epidemic encephalitis and meningitis.

Petersen, Montreal.

Spiral Movement in Man. A. A. Schaeffer, J. Morphol. **45**:293 (March 5) 1928.

When blindfolded persons walk, swim, drive an automobile, or call directions to the driver of an automobile in what they intend to be a straight path, 300 steps or more in length, they actually move in a more or less regular clock-spring spiral. The diameters of the spiral turns in walking and swimming varies from about 36 to 6 meters, in automobile driving from about 100 to 12 meters. The drift of the spiral turns is, in nearly every case, in the same direction in which the first turn was made. A spiral path is also made when walking backward, but the spirals are smaller than when walking forward, and the drift of the spirals is frequently opposite in direction to that in which the first spiral turn was made. The spiral turns are not due to asymmetries in the legs or other parts of the locomotor organs or of the body generally. One person may make both right spiral turns and left spiral turns in different experiments or sometimes in the same experiment. No difference is observed that is referable to differences in age, sex, or right-handedness or left-handedness. There is marked individuality in the paths which different persons make, in the size of the spiral turns, in the number of reversals from right to left turning and in other characteristics. The mechanism which causes the spirality of the path in man must be located in the central nervous system, probably in the "center" of one or more cells that coordinates locomotion at any given moment.

Spiraling is not a conscious phenomenon. A blindfolded person is conscious of moving in a straight path when he is actually spiraling. A manic-depressive patient and an imbecile, when blindfolded, walked essentially the same kind of a straight path as normal persons. The spiraling mechanism guides the path of persons who lose their way in forests, fogs, etc., and of rabbits, foxes, antelopes and other game when, hard pressed in the chase, they lose the power of orienting through fear.

The spiral path of man is interpreted to be the graphic expression in two dimensions of space of a helical spiral "pattern." The spiral path of man seems to be produced by the same mechanism which produces similar paths in blindfolded birds and mice and in rotifers, ciliates, flagellates, *Oscillatoria,* spirochetes, ciliated larvae of marine invertebrates, spermatozoa, zoospores, etc., and is, in fact, just a special case of the general phenomenon that all motile organisms move in a helical spiral or a projection thereof on a plane surface, when not guided by orienting organs. Of all the spiral turns of thirty-seven persons, the right predominated over the left in the ratio of 1.48 to 1. The element of time is of comparative unimportance when it does not affect rate of movement. This investigation has brought out the interesting relation that there is present, in perhaps all motile organisms, a locomotor bilateral asymmetry, which means that at any given moment an organism is either strongly right-turning or strongly left-turning, with a structurally definable side as a reference point. This asymmetry is reversible in those organisms confined to move in two dimensions of space, but fixed for apparently all other organisms.

Wyman, Boston.

The Pathologic Anatomy of Influenza: A Review Based Chiefly on German Sources. Franz Lucksch, Arch. Path. **5**:448 (March) 1928.

This article is a review of German investigations into the pathology of influenza. The causative factor of influenza has not been established, but the author inclines to the view that the influenza bacillus has two forms — one a visible form (appearing in cultures), the other a filtrable form not visible by ordinary methods. Two kinds of pathologic changes are observed: inflammatory lesions induced by the exciting organism and appearing first at the point of invasion and later in all parts of the body, and degenerative lesions caused by toxic products eliminated by the organisms and affecting chiefly the parenchymatous organs, including the heart, blood vessels and central nervous system.

Respiratory, intestinal and nervous forms of the disease occur. The author discusses the pathologic anatomy of these forms at length. In the respiratory form, thromboses of the arteries, veins and sinuses of the dura mater have been found. It is not yet possible to differentiate reliably which manifestations of the nervous form are due to the organism itself and which are the result of toxic products. Purulent pachymeningitis and hemorrhagic inflammation of the dura occur as extensions from lesions of the bone, sinus or middle ear. Redness and edema, hemorrhage into the pia-arachnoid, and serous leptomeningitis are usually the result of a toxic process. Mild inflammations of the pia-arachnoid are relatively common and are due to the presence of the bacillus. Purulent meningitis is more rare. Hemorrhagic encephalitis probably results from toxins. The author discusses influenza and epidemic encephalitis at length. As a transition between the lesions of the two conditions is histologically possible, and as etiologic and experimental research has not revealed a separate causative factor for epidemic encephalitis, he concludes that the syndrome called epidemic encephalitis is due to the action of poisons that appear in the body in influenza. It is still uncertain what these poisons are.

The spinal cord is affected much less frequently than the brain. The pathologic anatomy of the lesions that affect the peripheral nerves is unknown. He considers that the anatomic changes in the last epidemic of influenza differ from those of former epidemics, mainly, in their seriousness. Pseudomembranous inflammations and metaplasia of the epithelium of the respiratory passages were not found in former epidemics. The most striking phenomenon of the last epidemic was the frequent and grave affection of the central nervous system. This review is a comprehensive discussion of the whole question of influenza and should be read in the original by those interested.

Pearson, Philadelphia.

The Effect of the Extirpation of the Lens Rudiment on the Development of the Eye in Amblystoma punctatum, with Special Reference to the Choroid Fissure. Cora Jipson Beckwith, J. Exper. Zool. **49**:217 (Oct. 5) 1927.

In the embryo of *Amblystoma punctatum*, when the lens-forming ectoblast is removed in the neural-fold stage and replaced by foreign ectoblast, no lens is formed from this graft. In the absence of the lens, in all but a few exceptional cases, the choroid fissure fails to close during the later development of the eye, but remains open, the optic nerve running along the open groove to the brain. The presence of the lens, then, is apparently an important factor for the normal development of the choroid fissure and the optic cup. In a few of the older embryos, in the absence of the lens, a late adjustment has taken place, so that the choroid fissure is closed. The optic nerve may come off from the eyeball too far ventrally, suggesting a late closure. Some influence other than the presence of the lens is present in these forms. It is effective only in a late stage of development and is not sufficiently strong to replace the influence of the lens in more than a few cases.

In about 25 per cent of the embryos studied, a lens regenerated from the dorsal rim of the optic cup (iris) in a way practically identical with that process described in other amphibians. In all embryos in which a lens was formed or was forming in this way from the iris, the choroid fissure was closed normally or closing if the lens anlage was extremely young. The eye was normal in position and structure. This further confirms the existence of a causal relation between the presence of the lens and the ability of the choroid fissure to complete its closure. Lenses of this kind were not developed in embryos in which the optic cup showed a dorsal anterior thickening, thus bringing the pupil ventroposterior in position, or in forms in which there is an eversion of the whole cup. They did appear in eyes in which the pupil was lateral or ventrolateral in position whatever the type of modification present in the eye.

That the choroid fissure is not specific and localized is shown by a series of experiments in which the whole optic vesicle was rotated 180 degrees, since the choroid fissure appeared in every case on the new ventral side (original dorsal) of the optic cup. This was true whether or not a lens was present. Since the vitreous humor fails to form in eyes in which the lens is absent and the optic cup is collapsed or folded, these experiments may throw some light on the debated question of the participation of the lens in the development of the vitreous humor.

Wyman, Boston.

A Necrobiotic Focus in the Right Cerebral Hemisphere. A. P. Timmer, Ztschr. f. d. ges. Neurol. u. Psychiat. **108**:525 (May) 1927.

Timmer reports the case of a man, aged 79, who had had a psychosis since 1913. He did not work, remained at home, was without ambition, and refused to eat. On admission to the hospital he was catatonic and negativistic. He lay quietly in bed, did not speak and had to be fed. After a year there were periods during which he was free of catalepsy and others when he was cataleptic. The dementia, however, increased and he became disoriented for time and space; he finally became totally demented. Physically he showed severe arteriosclerosis; the condition was diagnosed as a psychosis with cerebral arteriosclerosis. In 1922, there developed a parkinsonian attitude. In 1923, six months before death he developed a left hemiplegia.

The necropsy revealed, in addition to cerebral arteriosclerosis, a peculiar focus around the fossa sylvii between the temporal and parietal lobes and enclosing the middle cerebral artery. The vessel, which was practically obliterated and showed an invasion by secondary capillaries, was the seat of an endarteritis obliterans of syphilitic or arteriosclerotic origin. The brain tissue in this focus showed good differentiation between cortex and white matter. The latter was brittle, however, and fell into pieces when handled. The entire focus was sharply demarcated from the surrounding brain substance. Cell stains revealed a homogeneous area in the focus, in which the ganglion cells had lost the Nissl's bodies and nuclei. Bielschowsky stains showed a loss of fibrillar structure in the cells. Glia stains were not sufficiently satisfactory to conclude about the glial reaction in the focus. Timmer compares the focus in his case to the foci produced by injections into the blood stream of lycopodium, by Spielmeyer, in which there was a loss of the nuclei around the vessel involved, followed by absolute loss of detail or necrosis. This was followed by an invasion of the area of necrosis by cells from surrounding regions. At first these consisted of leukocytes, which became disintegrated, and later fibroblasts which filled in the focus. The fibroblasts also gave rise to phagocytic cells which cleared away the disintegrated products. Later these fibrous invasions were also lost and a cavity resulted. If the cavity was small the glia filled in the entire defect. Timmer considers the picture to be similar to that of a coagulation necrosis.

Alpers, Philadelphia.

Epidemic Meningitis. A Study of More Than 650 Cases with Especial Reference to Sequelae. Josephine B. Neal, Henry W. Jackson and Emanuel Appelbaum, J. A. M. A. **87**:1992 (Dec. 11) 1926.

The number of cases of epidemic meningitis occurring when there is no epidemic is small. The authors present a study of 654 cases occurring in New York in sixteen years during which there had been no epidemic. Tables giving seasonal, sex and age distribution are presented. There were 34.6 per cent in the first three months of the year, 33.5 in the second three months, 13.9 in the third and 18 per cent in the fourth quarter. There were 57.5 per cent males and 42.5 per cent females. In 166 cases the ages of the patients were under 1 year; from 1 to 2 years, 78 cases; from 2 to 3 years, 37 cases; from 3 to 5 years, 81 cases; from 5 to 10 years, 108 cases; from 10 to 20 years, 101 cases; from 20 to 30 years, 54 cases; from 30 to 40 years, 18 cases; from 40 to 50 years, 10 cases, and from 50 to 60 years, 1 case.

Symptomatology is discussed under the usual picture in older children and adults; the clinical picture in infancy; the septicemic type, and the fulminating type. A list of conditions that may cause confusion in diagnosis is given. Attention is called to the absolute diagnosis by culture of the meningococcus in the spinal fluid. Laboratory observations are discussed, with especial emphasis placed on examination of the spinal fluid. The authors advocate conservatism in treatment and describe their method in considerable detail.

The mortality was nearly 30 per cent, and is explained by the fact that a large percentage of the patients were under 1 year of age, and that there were many contributing factors such as pneumonia. Under 1 year the mortality was 46.5 per cent; from 1 to 2 years, 29.2; from 2 to 5 years, 20; from 5 to 10 years, 20.2; from 10 to 20 years, 23.7; from 20 to 30 years, 34, and over 30 years, 30.8 per cent. In cases that ended in recovery, this was complete in 82 per cent while in 18 per cent there were sequelae which were often serious. The most common sequel was deafness, usually complete and bilateral. Other sequelae were paralyses, mental disturbances, defects of vision, headaches, speech defects, sphincteric disturbances, general weakness, pachymeningitis and transverse myelitis.

Chambers, Syracuse, N. Y.

Anatomic Distinction Between the Sexes. S. Freud, Internat. J. Psycho-Analysis **8**:133 (April) 1927.

Freud here pursues further his investigations regarding the fate and manner of dissolution of the Oedipus complex, and announces some results of his analytic research; he emphasizes that these are not proved, but feels justified in publishing them because "the time before me is limited" (Freud is now 72), and he hopes that his fellow workers may "make use of what is unfinished or doubtful."

The sexual life of the male child has been the most constant subject of investigation in psychoanalysis because the Oedipus complex is the first stage that can be recognized with certainty. Elsewhere, Freud has shown how the Oedipus attitude in little boys succumbs to the fear of castration, but he states that what precedes the Oedipus complex in boys is far from clear. The possibilities are that it is set into activity by the earliest infantile onanism and suppression of the latter by the persons in charge of the child. The training incidental to breaking the habit of bed wetting may also play a rôle.

In boys the mother is the original love object, and there is little wonder that the boy should wish to retain it; but what happens to induce the girl to abandon the mother and take the father as a love object? The girl, becoming aware of the absence of a penis, "almost always" holds her mother, "who sent her into the world so insufficiently equipped," "responsible for her lack of a penis"; this in turn loosens the hold of the female child on the mother as a love object. Instead of a penis she longs for a substitute for a penis, a child,

and with "this object in view, she takes her father as a love object." Her mother then becomes an object of jealousy, and the girl has become a little woman. The Oedipus complex in girls is, therefore, to be considered as a secondary formation. Freud summarizes his observations as follows: "Whereas in boys the Oedipus complex succumbs to the castration complex, in girls it is made possible and led up to by the castration complex." The castration threat inhibits and limits masculinity, whereas it encourages feminity because, in the female, the equivalent of castration is an act already carried out. The girl must become reconciled to castration, as the motive for the destruction of the Oedipus complex is lacking. In boys, the complex is literally smashed by the shock of a castration threat, desexualized and partially sublimated, and its objects are incorporated into the ego where they form a nucleus of the super-ego.

OBERNDORF, New York.

ART IN SCHIZOPHRENIA. E. MASCHMEYER, Arch. f. Psychiat. u. Nervenk. **78**:510 (Oct.) 1926.

On the basis of a study of two cases of his own and the literature on the subject, the author discusses the question of the expression of schizophrenic trends in artistic form. The first case is that of a man, aged 35, who, before the onset of the psychosis, had done a good deal of painting without, however, any tendency toward originality. For three days preceding the psychosis, he worked feverishly on a new picture. On its completion he began to show increased psychomotor activity and to express ideas of reference, which passed gradually into an acute schizophrenic excitement. He began to develop ideas of grandeur, and wrote a one act play in which he was the center of a revolution in the art of painting. The picture was full of symbolic expression but showed conservation of formal logic; its title was the famous "Stirb und Werde" of Goethe. The various historic periods preceding the present age were represented symbolically, and the patient himself was shown in the picture as the originator of a new idea in the form of a structure overshadowing all others.

The second case is that of a gradually developing schizophrenic psychosis in contradistinction to the acute condition of the first. Another point of difference lies in the fact that the second patient had always shown signs of originality in his paintings. Here, too, there was a great deal of symbolism, but also a certain degree of good artistic taste, and the individuality of the artist was preserved throughout in the style.

The author discusses the similarity between the paintings of the two artists and sees in their symbolisms and originality an expression of the unconscious conflicts and desires of the patients. The author suggests that there is a certain similarity between the creations of this type and those of the masters of art in general.

MALAMUD, Foxborough, Mass.

INTRODUCTORY STUDY OF THE EROTIC BEHAVIOR OF IDIOTS. HOWARD W. POTTER, J. Nerv. & Ment. Dis. **65**:497 (May) 1927.

A cross-section study, by objective methods, of erotic behavior of 398 idiots of both sexes was made while the subjects were patients in a large institution for mental defectives. The prevalence of a sex desire, its sexual object and its mode of expression were determined and correlated with the sex and physical maturity of the patient. Nearly three quarters of the entire group showed the presence of erotic desires; the percentage was larger in females than in males, and, in general, it was present in a larger proportion of adolescents than of those who were older or younger. Nearly four fifths

of the total erotic idiots were autoerotic only. They did not show any sex drive directed outside the sphere of their own bodies. The remainder, in addition to being autoerotic, directed their sex interests to associates (of the same sex) as well. There seemed to be more extroverted sex interest among the males than among the females, and postadolescents of both sexes showed more extroversion than either adolescents or preadolescents.

The erotic desire was expressed in forms of genital or pregenital eroticism and perverted eroticism, as masturbation, mutual masturbation, rocking motions, sadomasochism, oral and anal eroticism, pederasty, cunnilingus and fellatio, in order of frequency. In general, masochism was more common among preadolescents; masturbation, rocking motions, oral eroticism and fellatio among adolescents; sadism, mutual masturbation, pederasty, cunnilingus and anal eroticism among postadolescents. Masturbation and mutual masturbation were more common among the males — the other forms among the females.

The author concludes that idiots do not present a sexuality any more organized than their primitive intelligence, and he raises the question whether psychosexual development does not depend, for at least part of its normality, on the type of intellectual equipment. Does the infantile fixation of the psychosexual result sometimes in a fixation of the intelligence at a low level of development, or do both intellectual deficiency and psychosexual fixation depend on a more fundamental situation? In any case, the survival of the fittest is secured by the lack of procreational urge in these biologically unfit organisms.

Hart, Greenwich, Conn.

The Reactions of Parkinsonian and Catatonic Patients to Fright as Compared with Those of Normal Persons. K. Zucker, Arch. f. Psychiat. **79**:531 (Feb.) 1927.

The material consisted of 66 men (24 normal; 13 with a parkinsonian syndrome, both true and postencephalitic; 3 with juvenile parkinsonism, and 26 catatonic patients) and 42 women (18 normal; 9 with a parkinsonian syndrome; 15 catatonic patients). The reactions to fright were divided into two components: somatic and psychic. In testing the former the stimulus was furnished by clapping together two pot-lids at a certain distance behind the subject, who was resting quietly and was not aware of the nature of the experiment. The pulse and respiration rate were recorded on a kymograph throughout the experiments. The stimulus for the psychic component was furnished by dropping a large pail on a stone floor. Throughout the experiment, the subject was required to repeat digits given by the examiner. The number of digits varied with different persons, depending on the previously determined maximal ability of each subject. After the experiment was performed, the subjects were requested to describe their feelings of fright in response to the stimulus in terms of none, slight, moderately marked, marked or very marked.

With the normal persons the factors of importance were: the female subjects reacted more strongly than the male (this remained true throughout the series); the normal subjects showed variations within fairly narrow limits. The akinetic parkinsonian persons showed marked decrease in somatic reactions, with only a slight decrease in the psychic component. The juvenile metencephalitic persons (akinetic syndromes), however, showed a normal type of reaction (only three were tested). The catatonic persons were divided into two groups: (1) those with slight, and (2) those with marked emotional deterioration. The former showed a type of reaction that was directly opposite to that of the parkinsonian patients; the somatic reactions (pulse and respiration) were practically normal, whereas the psychic reaction was almost nil. The second group of catatonic patients showed little reaction in either component.

Malamud, Foxborough, Mass.

THE REFLEX OF THE EXTERNAL MALLEOLUS AND THE PIETROWSKI PHENOMENON. SAGIN and ST. OBERC, Monatschr. f. Psychiat. u. Neurol. **64**:252 (July) 1927.

This report presents a critical discussion of an article by Balduzzi on the same subject. The authors, referring to the original descriptions of the reflex, distinguish two types: (1) The Anticus Reflex (Reflex of the Tibialis Anticus): Tapping the belly of the tibialis anticus at or just below its origin often causes dorsal flexion and supination of the foot. The optimal position for eliciting the reflex is with the patient in the dorsal decubitus position with the foot rotated in, or with the leg hanging relaxed. This reflex was described by Pietrowski, but is not the Pietrowski reflex. It is a physiologic reflex and is found in many normal persons. (2) The Antagonistic Reflex of Pietrowski, or Pietrowski Reflex: Tapping the belly of the tibialis anticus produces, instead of the normal dorsal flexion and supination, an isolated plantar flexion of the foot. Instead of a contraction of the tibialis anticus, as in the physiologic reflex described under (1), there occurs a contraction of its antagonist, the gastrocnemius. The effect can be increased by making the test with the foot a little dorsally flexed. This reflex is pathologic, and is found only in organic disease of the central nervous system, especially of the brain.

In certain cases, the reflexogenic zone of the Pietrowski phenomenon is greatly increased; the reflex can then be obtained from a wide area of the leg, including the external malleolus. But this reflex of the external malleolus is not an independent reflex; it is merely an extension of the Pietrowski phenomenon. In some cases the physiologic and pathologic reflexes — the anticus reflex and the antagonistic (Pietrowski) reflex — coexist.

SELLING, Portland, Ore.

AGITATION OF THE FOOT: A NEW METHOD OF ELICITING A PYRAMIDAL TRACT SIGN. J. A. SICARD, Presse méd. **25**:257 (Feb. 26) 1927.

This new sign is said to have been positive in a number of cases of paraplegia in which neither plantar scratching nor dorsal pinching of the foot gave rise to any response. In these cases ankle clonus was also absent, though the Mendel-Bechterew sign could be elicited. The cases were examples of spastic paraplegia from compression of the spinal cord, or of unknown central origin, with normal, diminished or lost, but not exaggerated, deep reflexes. The sign was found less useful than the classic ones in cases of cerebral hemiplegia with contracture. It was negative in normal and in parapyramidal cases.

This sign is elicited by grasping firmly the lower third of the leg, and shaking the foot vigorously from side to side; this movement should be continued rapidly for about half a minute, while the foot is either kept raised or, preferably, permitted just to touch the surface of the bed, and it should be stopped suddenly. The positive response is a momentary extension of the great toe, an extension of all the toes, an extension of the great toe and flexion of the other four, a dorsiflexion of the foot or an associated flexion of the foot and the leg.

HUDDLESON, New York.

INFLAMMATION OF THE CENTRAL NERVOUS SYSTEM: II. THE EFFECT OF THYROID, TESTICULAR, OVARIAN AND HYPOPHYSIAL EXTRACTS ON INFLAMMATION. J. NAKAMURA, Arb. a. d. Neurol. Inst. a. d. Wien. Univ. **29**:50, 1927.

The object of this investigation was to determine the effect of the hormones of the thyroid, testicular, ovarian and hypophysial glands on aseptic inflammation of the central nervous system. The experiments were conducted on guinea-pigs; the brains were traumatized under aseptic precautions by a simple stab wound, and the animals were allowed to survive for seven days after the injury. Some of the animals were injected with hormones before

the trauma, others afterward, whereas the control animals did not receive hormones at all. Nakamura concludes that the hormones have a definite, though not marked, effect on the reactive inflammatory processes. This effect is manifested by increased metabolism—a premature destruction of the broken down cells; it is most marked after the injection of thyroid, less marked after the injection of solution of pituitary, and still less marked after testis; ovarian hormone seemed to have the least effect. Altogether, these hormones seem to influence favorably the formation of scavenger cells, but exert little influence on the reparative processes.

KESCHNER, New York.

COLOR VISION IN THE MUDMINNOW. GERTRUDE M. WHITE HINELINE, J. Exper. Zool. **47**:85 (Feb. 5) 1927.

Further experiments were undertaken to test the power of association and color discrimination in the mudminnow, *Umbra limi* (Kirtland). The food taking activities were studied under monochromatic lights of equal radiant energy afforded by light from a mazda lamp passed through Wratten monochromatic gelatine light filters. It was concluded that mudminnows are able to form associations of food and inedible substance with certain monochromatic lights of equal energy. The experiments indicated that mudminnows are able to distinguish between the following colors when these are equalized for total energy: red and green; red and blue; red and yellow, and yellow and blue; but probably not blue and green. Since the monochromatic lights used transmit equal total energy, the associations formed by the fish are due to differences in the quality of the light, and are evidence that mudminnows have at least the beginnings of color vision.

WYMAN, Boston.

A CASE OF CEREBELLAR TUMOUR. A. GURNEY YATES, Lancet **1**:78 (Jan. 14) 1928.

The case reported is that of a child, aged 5 years, who gave a history of purulent discharge from the right ear since the age of 8 months. For several weeks previous to admission to the hospital, she had had occasional attacks of biliousness and for three weeks almost daily vomiting. She also had headache, an unsteady gait and a sluggish mentality. The right pupil was larger than the left, but both reacted to light and in accommodation. The right disk showed slight swelling, the left was normal. There was an internal squint from paralysis of the right sixth nerve. The right ear was discharging, but there was no tenderness over the mastoid. Both arms and both legs were ataxic, the condition being most marked in the right arm, the muscles of which were atonic. Biceps, triceps, knee and ankle jerks were absent. The plantar response was flexion on both sides. A provisional diagnosis of right-sided cerebellar abscess was made, but pus was not found on exploration. At autopsy the cerebral convolutions were seen to be flattened, and the ventricles were greatly distended. There was a pressure cone on the inferior aspect of the cerebellum, and a glioma was found in the right lobe of the cerebellum.

PETERSEN, Montreal.

NORMAL AND PATHOLOGIC CHANGES IN THE HUMAN EPIPHYSIS. ERNST WEINBERG, Fol. Neurop. Eston. **6**:57, 1926.

Weinberg's summary is as follows: 1. The observations reported by Walter (Marburg, Josephy and others to the contrary) show that the pineal cells are supplied with protoplasmic processes. 2. These processes are brought out, not only by means of special methods of impregnation, but also by ordinary staining reactions. 3. In some pathologic conditions, particularly those associated with increased intracranial pressure, these processes, as well as the protoplasm itself, become thicker and more succulent (Walter's hypertrophy). 4. It seems that this does not comprise an increase in the number of cells, but only hypertrophic changes

in the protoplasm of individual cells. 5. In the youthful pineal body under pathologic conditions the pineal cells become arranged in palisade fashion. At the border of the connective tissue this arrangement is also to be found. The basal end of the cell becomes smaller with increasing age and finally changes over into delicate threads. 6. In age, only seldom is the connection between processes and cells to be seen.

FREEMAN, Washington, D. C.

THE EFFECT OF CERTAIN PHYSICAL AND CHEMICAL FACTORS ON LOCOMOTION AND OTHER LIFE-PROCESSES IN AMOEBA PROTEUS. D. L. HOPKINS, J. Morphol. **45**:97 (March 5) 1928.

Form, consistency, rate of growth, rate of multiplication and rate of locomotion in *Amoeba proteus* depend on the hydrogen-ion potential of the solution in which it is immersed. The rate of locomotion in *Amoeba* depends on the osmotic pressure of the surrounding medium. There is an optimum external osmotic pressure for locomotion which varies with the hydrogen-ion concentration. The rate of locomotion in *Amoeba* seems to be dependent on the water content and it appears that the water content is in some way dependent on the hydrogen-ion concentration of the surrounding medium.

WYMAN, Boston.

STUDIES IN ACROMEGALY: VI. THE DISTURBANCES OF CARBOHYDRATE METABOLISM. L. M. DAVIDOFF and HARVEY CUSHING, Arch. Int. Med. **39**:751 (June) 1927.

Concerning glycosurias accompanying acromegaly the writers conclude that even though patients suffering from this disease may not have spontaneous glycosuria, they have a low sugar tolerance with a tendency to hypoglycemia. This glycosuria is peculiar in that the patient occasionally recovers spontaneously; this seldom, if ever, happens in true pancreatic glycosuria. The condition is affected to some extent by insulin therapy, but by no means to the extent that this drug is effective in true diabetes. This is presumably due to the antagonistic action of pituitary extract. It follows that partial extirpation of the pituitary adenoma will probably render the patient more susceptible to treatment with insulin.

ANDERSON, Philadelphia.

A CASE OF NERVE PALSY. NATHAN WALSH, Lancet **1**:129 (Jan. 21) 1928.

The case is that of a patient who suddenly, during a football game, developed pain along the outer side of the left leg. This grew worse and there appeared, about 2 inches below the head of the fibula, a red, stony hard and tender swelling. He could not dorsiflex the ankle nor abduct the foot. There was neither wasting nor sensory change. Roentgen-ray studies did not show abnormality. The diagnosis was that of paralysis of the anterior tibial nerve due to rupture of fibers of either the peroneus longus or the extensor digitorum longus with a hematoma compressing the nerve. Under treatment with massage and electricity he is slowly improving.

PETERSEN, Montreal.

THE NERVOUS SYSTEM OF PELAGIC NEMERTEANS. WESLEY R. COE, Biol. Bull. **53**:123, 1927.

The nervous system of certain deep-sea worms is described in this paper and is illustrated with clear cuts. The arrangement of the nerve cells in the lateral nerve cord as well as the fact that the nervous system varies with the environment is of special interest. Certain sense organs that are conspicuous in the forms living at the bottom of the sea are absent in these floating deep-sea worms.

COBB, Boston.

THE TREATMENT OF ANXIETY. E. VARELA DE SEIJAS, Arch. de neurobiol. **7:** 182 (July-Aug.) 1927.

Anxiety, a symptom in many mental diseases, is discussed. From personal experience, the author believes that among the best remedies against anxiety are dietetic measures to relieve the organism from overproduction of toxins, warm baths of long duration and administration of derivatives of barbituric acid of the type of phenobarbital and its cyclohexanic homologs, as well as intravenous injections of calcium.

NONIDEZ, New York.

INFANTILE PARALYSIS. EDITORIAL, J. A. M. A. **89:**1062 (Sept. 24) 1927.

Public fears of infantile paralysis are well warranted in view of the serious harm wrought by the disease in many cases and also in view of the uncertainty as to the causative organism and as to the lack of any certain method for prevention or cure. A brief resumé of Frost's recent summary of knowledge of the disease follows.

CHAMBERS, Syracuse, N. Y.

THE INFLUENCE OF PARTURITION UPON INSANITY AND CRIME. A. LOUISE MCILROY, Lancet **1:**379 (Feb. 25) 1928.

This article, a lecture delivered by the professor of obstetrics and gynecology of the University of London (Royal Free Hospital) to the Medico-Legal Society, reviews English law in its relation to infanticide and the influence of insanity in this regard.

PETERSEN, Montreal.

Society Transactions

GERMAN NEUROLOGICAL SOCIETY

Seventeenth Annual Congress held in Vienna, Sept. 15 to 17, 1927

ABSTRACTED BY W. J. BERNIS, M.D., ROCHESTER, N. Y.

(Deutsche Ztschr. f. Nervenh. **101**:88 [Jan.] 1928)

In his presidential address, O. Förster paid tribute to the influence which Viennese physicians have exercised in the field of neurology. Among the first stands the name of Ludwig Türck. He was primarius in the Allgemeinen Krankenhaus and is generally considered the father of laryngology. Türck, however, was interested also in the anatomy of the nervous system. His most important discoveries belong to the early fifties of the last century; he discovered the pyramidal tracts and the temporopontile bundle still bears his name. In his study of the fiber systems he employed the method of secondary degeneration. At about the same time Nathan Weiss published a careful study on tetany.

Herrmann Nothnagel was active in Vienna from 1880 to 1904. His great contribution was in stressing the importance of neurology to internal medicine. He is to be remembered especially for establishing topical brain diagnosis and for his work on epilepsy. Among Nothnagel's foremost pupils were Frankl-Hochwart, Hermann Schlesinger, Pineles, H. Lorenz, Hatschek, A. Fröhlich, A. Bauer, R. Stern, Marburg, Donath and Reinhold.

Otto Kahler, an internist of that time, with A. Pick published research work on combined tract diseases and on posthemiplegic motor disturbances. Among his pupils were Frederick Kraus, of Berlin (whose lectures at the second Medical Clinic always attracted many American physicians) Adolf v. Strümpell and Franz Chvostek.

Theodor Meynert was active in Vienna from 1865 to 1892. He discovered the different regional structures in the brain, and painstaking anatomic studies of the brain led him to the discovery of the projection fiber system, the commissural and the association systems; he therefore may be considered the father of the architectonics of the brain. Among his pupils were Huguenin, Fritsch, Hollander, Schnopfhagen, Kuffner, v. Pfugen, Gabriel Anton and Carl Meyer. Carl Wernicke considered himself a spiritual child of Meynert. Among Gabriel Anton's pupils were Hartmann, Zingerle, Albrecht, Phelps, Di Gaspero, de Crinis, Pfeiffer, Schilder, Willige, Knauer and Pönnitz. Among Carl Meyer's pupils were Stiefler, Camper, Untersteiner, Scharfetter and Reisch.

Krafft-Ebing succeeded Meynert in 1892. From his school came v. Soelder, Halban, Isufeld, A. Fuchs, Karplus and Hirschl.

In 1902, Wagner v. Jauregg became chief of the neurologic department. His influence in the field of neurology and psychiatry is so well known that it hardly needs mention. Last year he was awarded the Nobel prize for introducing malaria in the treatment of general paralysis. Among his pupils are Emil Redlich, Pilcz, Raimann, Stransky, Mattauschek, A. Fuchs, Eltzholz, Pötzl, Straubinger, Bonvicini, Economo, Schüller, Marburg, Kogerer, Schilder, Schacherl, Pappenheim, Frisch, Gerstmann and Sträusler.

Among the outstanding neurologists of Vienna is Heinrich Obersteiner. Even today his textbook is an authority on the finer anatomy of the nervous system. The neurologic institute which he organized is one of the leading research institutions in neurology. Among his many pupils may be mentioned Marburg, Redlich, Cassirer, Spiller, Schlesinger, Frankl-Hochwart, Hatschek, Karplus, Pilcz, Raimann, Pineles, Bikeles, Stransky, Economo, Pötzl, Dexler, Mager, Schacherl,

Schilder, Bauer, Zappert, Neurath, Spiegel, Pollak and Hoff. Students went to him from all parts of the civilized world. Nearly the entire neurologic school of Japan received its inspiration from Obersteiner.

In Otto Marburg the Institute found a worthy successor who in every way has maintained its tradition; he is universally considered a towering pillar of present day neurology.

Other names in this period to be mentioned are Moritz, Benedikt, Brewer, Probst, R. Sternberg, S. Freud, and his pupil Alfred Adler. (It seems strange that Prof. Förster should have omitted the names of two men who came from Vienna, Gall and Messmer.)

Neurology also owes much to Viennese physicians engaged in other branches of medicine. Among the anatomists were Zuckerkandl, who investigated the olfactory fiber, his pupil and successor Tandler, Hochstetter, who studied the embryology of the nervous system, and Fischl who worked on the spinal cord.

Among physiologists were Brüke, S. Exner, whose work on the function of the human brain is monumental, and Kreidl, his pupil, whose work with Karplus embraces the tuber cinereum, the sympathetic system and the tract for pain in the spinal cord. Spitzer, with Karplus, made anatomic experiments on lesions in the pons.

The names of Rokitanski, Cundrat, Weichselbaum, Kolisko, Stricker, Pal, Erdheim and Marisch must be mentioned among pathologists who have contributed to the advancement of neurology. Among pharmacologists were N. H. Meyers and Fröhlich. The endocrine school ðf Vienna has furnished a long list of names, including Biedl, Falta, Heppinger and Hess.

The schools of ophthalmology, otology, laryngology, surgery, orthopedics and roentgenology have each furnished many men who have contributed greatly to the advancement of neurology; among them were Fuchs, Mauthner, Bernheimer, Pollitzer, Carl Ludwig, Heinrich Neumann, Victor Hammerschlag, Gustav Alexander (who in collaboration with Otto Marburg recently published a monumental work "Die Neurologie des Ohres"), Bárány, Hajik, Eiselsberg, Dernk, Holzknecht, Schüller and Jellinek.

Förster's address is a remarkable historical document. It calls attention to what the Vienna medical center has contributed to neurology, from which it may be inferred that its influence was not less in the other branches of medicine.

Anatomy, Physiology and Pathology of the Sensory Systems. Dr. A. Wallenberg.

Wallenberg dealt mainly with the anatomy of the sensory systems. The largest number of the exteroceptive end-organ fibers may be considered as the peripheral continuation of spinal ganglion cells and of homologous cranial sensory ganglion cells. With them become closely associated tangoceptor fibers which serve touch, pressure, pallesthesia and their modifications. They form the transition to the peripheral path from the proprioceptive end-organs of deeper parts — muscles, ligaments, joints, periosteum and cartilage. It is doubtful whether all of the latter have their trophic center in the spinal ganglion cells. According to Förster, there are centripetal anterior root cells in addition to those of the posterior root. Dart assigns the entire protopathic receptors to the sympathetic and only the epicritic receptors to the cerebrospinal system.

The sensory visceral fibers from the end-organs of the blood vessels, the mucous membranes, the exocrine and endocrine glands, the thoracic and abdominal organs, and the mediastinal, intestinal and cerebrospinal coverings, pass by way of the intramural, prevertebral, vertebral and cranial ganglia and the rami communicantes to the cerebrospinal ganglia. There is no anatomic evidence for the belief that they also make use of anterior root cells in their passage to the central organs, especially that the sensory splanchnic fibers pass through cells of the anterior root. Kidd, in 1911, saw afferent fibers in the neighborhood of the anterior root cells, some of which came from the smaller cells of Clarke's column, some from medium sized and posterior horn cells and some from the

nucleus cuneatus bulbi, in man largely limited to the thoracic and lumbosacral regions. It is still uncertain whether Hoche's cells, the lumbar anterior root cells, and the Takehashi-Allen cells in the neighborhood of the portio minor trigemini can play the part of spinal ganglion cells. Jacobsohn-Lask observed at times in the human fetus a small bundle between the periphery of the spinal cord and posterior root, which apparently entered the anterior root. This might have been merely a fillet formation of the posterior root as it enters from the spinal ganglion. Förster is of the opinion that pain from the abdominal organs is carried largely by way of the sympathetic nervous system, especially over the periarterial net of the aorta and the visceral arteries; it is uncertain whether, and to what degree, the afferent fibers of the vagus and the phrenic nerves also serve as pain transmittors. According to Förster, not only do a part of the deep sensory fibers and a small number of cutaneous elements pass by the anterior roots, vicarious to the posterior roots, but also some fibers of the radicular tract for visceral sensibility, which in the main passes through the posterior root, pass to the anterior root. According to Kölliker-Langley splanchnic myelinated fibers pass uninterruptedly from the periphery through the celiac ganglion, the splanchnic, the sympathetic, the rami communicantes albi, the thoracic spinal nerve, with a trophic center in the spinal ganglion, and enter the posterior roots of the spinal cord like the nonautonomic sensory fibers. According to others, nonmyelinated splanchnic fibers, with trophic centers in the celiac ganglion or in the sympathetic system, pass through the rami communicantes albi and spinal nerves to the spinal ganglion; there they break up near cells whose axons pass into the spinal cord as posterior roots, around cells that have only a central neurite, or around the ordinary ganglion cells that have a central as well as a peripheral neurite. This offers the well known explanation for the zones of Head. Afferent gray sympathetic fibers may also split up at the spinal ganglion cell, the central neurite of which passes on to the spinal cord by way of the anterior roots, or the splanchnic myelinated fibers may pass without interruption from the periphery to the spinal ganglion cells, the central neurite of which becomes the afferent anterior root. Förster recalls Shawe's theory that the afferent fibers which enter the anterior roots have their trophic center in the spinal cord itself.

The spinal ganglion cells are of a variety of types. Dogiel recognizes seventeen types. Clarke, in dogs and other mammals, found seven types according to the grouping of the Nissl bodies, the relative number of which remains constant and possesses a relation to function. Ranson saw only five types in the dog. The number of ganglion cells in a spinal ganglion greatly exceeds the number of fibers in the peripheral nerve and in the posterior root. There are several explanations for this. Ranson assumes that the number of small cells, whose peripheral neurite is nonmyelinated, is larger than the large cells, the neurites of which become myelinated. Medwednikoff, after sectioning the third lumbar nerve, saw only a small number of degenerated spinal ganglion cells. The remaining cells must apparently be considered as those with short axons. Apparently, a large number of cells have only either a peripheral or a central neurite. A fine net around ganglion cells is said to represent the end fibrils of sympathetic fibers from the rami communicantes; in this way the visceral sensory stimuli pass on to the somatic sensory cells. According to Rossi, however, a few of the ganglion cells send their peripheral axons as afferent sensory fibers to the rami communicantes. Whether in man particular cell groups bear a relation to particular parts of the periphery, as is the case with the Gasserian ganglion of the trigeminus, or with particular sense qualities, Wallenberg was unable to state.

Not all posterior root fibers take origin in the spinal ganglion cells; it is rather to be assumed that the root contains fine, endogenous spinal fibers having a centrifugal direction. According to Timacheff, the number of these fibers in the dorsal cord of the dog amounts to about 5 per cent. The location of the spinal center is still uncertain. The largest number of the myelinated and nonmyelinated fine fibers separate from the rest before entering the root at the gliosed constriction zone, and pass on laterad to enter Lissauer's marginal zone, limiting dorsomedially the direct cerebellar tract. It contains also a large number of

myelinated and nonmyelinated endogenous fibers from cells in the substantia gelatinosa of the posterior horns. The largest number of the exogenous root elements end here. These fiber bundles had been considered by many authors as the carriers of the sensation of pain and by others as transmitting temperature stimuli, especially that of cold. From his own investigations on the human cord, Wallenberg cannot attribute such function to this area, since Lissauer's zone contains only a few myelinated exogenous posterior root fibers. Perhaps it may be considered, at least the endogenous part of it, as the phylogenetic perimedullary zone which in man passes on, at the caudal part of the medulla oblongata to the ventral margin of the nucleus of the spinal trigeminus root, a fact which is not commonly known. It has been repeatedly asserted that the spinal trigeminus root enters the upper cervical region at Lissauer's zone. This is not so. The spinal trigeminus root crowds the Lissauer zone more ventromedial (and assumes a topographic position in relation to the nucleus similar to that observed in fishes possessing the finer, especially nonmyelinated, fibers).

The major portion of the posterior root passes through the narrow glial zone and sends a thick-fibered lateral bundle through the substantia spongiosa and gelatinosa into the center of the posterior horns. Wallenberg occasionally observed extremely fine collaterals coming from the small Gierke's cells of the substantia gelatinosa and from some cells of the spongiosa, but real nerve fiber endings appear to come only from Lissauer's marginal zone. Wallenberg agrees with Marburg that the substantia gelatinosa is not to be considered as a nucleus sensibilis proprius.

The lateral root fibers form an imposing bundle in the center of the posterior horn, that is, in Clarke's ascending column, which may cover three segments and then enter into relation with the homolateral cell groups of the gray substance and apparently also with the paracentral groups of the opposite side by way of the dorsal commissure. The number of reflex fibers that pass to the anterior and lateral horn cell groups varies with the different segments. Little is known about the dichotomy of the lateral posterior root fibers and the remains of its descending twigs. Central and basal posterior horn cells may even now be considered as the main station; even the cells as far as the region of the lateral horn may be placed in this group, while the smaller cells between the horns and the base of the posterior horn, according to Marburg, apparently serve visceral sensory function. The relation of those root fibers to the marginal cells and to the cells of the processus reticularis is uncertain. The cells lying dorsally around the central canal, Marburg's Nebenzellen, and the ventral cells adjacent to the anterior commissure are to be considered rather as the origin of secondary visceral tracts; more than this cannot be established. There is no differential mark between the cell groups, between those from which the secondary sensory tracts proceed and those whose neurons function as association and correlation fibers. It is hard to state how far one is justified, from clinical observations, to separate the fibers in the posterior horn into those that lie laterally and serve for pain, those medial for heat and touch, and those between for the sense of cold; equally so is Förster's assertion that each segment of the posterior horn, in addition to its spinal ganglion and root relation, forms a functional entity in which the body metameres are reflected.

The proprioceptive tracts are much better known. The bundle fibers of the root lying to the inner border of the posterior horn end in the Stilling-Clarke's column. It contains in its lower dorsal and upper lumbar parts, on its medial half, fibers from the sacral cord and the fifth lumbar, and on its lateral half from the rest of the lumbar cord. The largest part of the medial posterior root fibers, after dichotomic division, regulates its tract formation in accordance with the law of excentric ordination of long tracts, thus forming independent areas for the individual roots, so that even in the upper cervical cord one can distinguish the different dorsal, lumbar and sacral areas. While Schülze's comma tract contains only few endogenous spinal elements as compared with the descending root fibers, the number of those fibers is quite large in Flechsig's oval bundle,

in Gombault's-Phillipe's triangular fasciculus, in Marburg's fasciculus longitudinalis septi, in Edinger's central posterior funiculus, and in Obersteiner's dorsomedial sacral bundle. Wallenberg considers that a part of most fibers of the medial dorsal root are sensory visceral with their endings in the cell groups dorsomedial to the central gray substance. The existence of a medial sympathetic column is questionable, although there are found in this area inconstant scattered cells that morphologically resemble the sympathetic cells of the lateral column. In the descending posterior funiculus, there are present centrifugal sympathetic and parasympathetic fibers for the bladder, intestines and the genitals, even though anatomically this has not yet been established. The author calls attention to Förster's hypothesis that the posterior funiculi contain fibers not only for the senses of touch, pressure, position, movement, discrimination of weight, space and of two point stimuli, and of the different dimensions, but also inhibitory fibers for the sensation of pain; thereby they act as a moderator of the old phylogenetic pain system. It is a corticifugal pain inhibitory tract which apparently passes over the border layer of the gray substance and reaches the pain functional cell elements of the posterior horn. Anatomically, such a tract has not been established in man. Rothfeld was able to follow a bundle containing myelinated fibers along both sides of the central canal and running the entire length of the cord; it has some relation to the commissures. A similar bundle is described by Marburg in the gray matter of the bottom of the fourth ventricle. A similar bundle was observed by the author running along the lateral border of Stilling-Clarke's column. The function of those bundles is not known.

After sectioning the dorsolateral root areas of the medulla oblongata, the author found a descending degeneration of the exteroceptive trigeminus fibers, of the proprioceptive lateral acoustic, and of the viscerosensory, glossopharyngeal and vagus fibers as far down as the cord; laterally the degeneration affected the trigeminus fibers; intermedially, the lateral acoustic proprioceptive, and most medially the interoceptive elements. He saw the sensory glossopharyngeal-vagus root end in the gray substance dorsal to the central canal, about in the middle cervical region, and in its caudal extension a medial ascending dorsal root of fine fibers, part of which entered also into the gray substance, dorsomedial from the spinal acoustic end-stations and the proprioceptive posterior roots.

The intraspinal course of the secondary tracts from the end nuclei of the lateral dorsal roots is well known. Of the two nuclei from which the crossed ascending tract finds its origin, the ventral one is considered as the nucleus intermedius sensibilis, the end nucleus of the dorsal cervical roots; it ends in the medulla oblongata and functions at the same time as a motor reflex and as a sensory nucleus, while the dorsal nucleus, cornu posterioris, anteriorly the substantia gelatinosa of the spinal trigeminus root, acts as the nuclear origin of the secondary trigeminus tract. Wallenberg called attention to the fact that the substantia gelatinosa rolandi is not the point of origin of the secondary trigeminus fibers.

The tractus spinothalamicus and the spinotectalis connect with the opposite midbrain and interbrain. Wallenberg has not changed his views on the position of these tracts for the different segment levels and for the different sense qualities. In the cervical cord, at the periphery of the anterolateral tract, is the tract for pain and temperature for the opposite lower half of the body; more medial, especially ventromedial, is that for the upper extremities. In the medulla oblongata and pons the tract lies dorsomedial from the rest of the spinothalamic fibers. The fibers for cold and pain apparently unite, while those for heat and a portion of the tactile fibers appear to lie nearer to the funiculus anterior.

With the exception of certain touch and pressure senses, which travel brainward in the ventral part of the opposite thalamic tract, the proprioceptive impressions ascend by the homolateral posterior funiculus and by the spinal cerebellar tracts of the same side.

It is possible that a part of the secondary visceral sensory tract ascends through the gray substance around the central canal, but another part, and perhaps the largest one, ascends near the opposite spinothalamic tract. Spiegel and

Bernis hold that the ventrolateral tracts carry centripetal visceral sensory stimuli, especially that of pain from the blood vessels, and believe that they are justified in assuming that frontally this tract connects more or less with the bulbar respiratory apparatus.

In front of the pyramidal decussation a change of position takes place; the exteroceptive roots change from dorsolateral to ventrolateral positions; dorsolateral to it are the proprioceptive, and dorsomedial the visceral sensory fibers. While the three functions are united in the spinal cord in one dorsal root, representing one segment, they separate in the cranial segments into independent nerves: the exteroceptive roots unite with the spinal trigeminus root, the proprioceptive higher up with the vestibularis, the viscerosensory attach themselves either to the trigeminus, the facial, the glossopharyngeal or the vagus.

Concerning the topography within the spinal trigeminus root, Wallenberg finds no reason for changing his earlier conceptions published in 1910. Most of the fibers for pain, heat and cold, and apparently also a part of the taste fibers of the trigeminus, end in the nucleus of the spinal trigeminus root, a lesser number end in the substantia gelatinosa rolandi. The ventral horn of the spinal trigeminus root carries the fibers for the area of the temple and forehead; dorsal to it run the fibers for the upper jaw and eyeball, then for the lower jaw, lips, the mucous membrane of the buccal cavity, and for the tongue, the last only in the neighborhood of the frontal pole. Dorsally, it is roofed by the frontal extension of the solitary bundle nucleus, and apparently that is where the trigeminus taste fibers end.

Recently, the course of the root fibers of the spinal trigeminus for pain has been under discussion. Allen found fine myelinated and nonmyelinated as well as thick myelinated fibers in all pulp nerves of the teeth. He concluded that any of the three may carry pain. Windle, on the other hand, believes that pain is carried largely by the poorly myelinated or nonmyelinated fibers. He pointed out that the trigeminal twig for the cornea contains mostly nonmyelinated or poorly myelinated fibers. The sensory trigeminus fibers entering at the pons divide into an ascending twig, for the sensory pontile trigeminus nuclei, carrying tactile fibers, and a descending twig to the spinal trigeminus root, carrying pain and temperature fibers. According to Windle, not all fibers of the sensory trigeminus root undergo bifurcation; the fibers follow a kind of grading. Beginning at the pontile main nucleus, there are thick ascending undivided fibers; at the spinal root nucleus the thin undivided fibers end; between are many fibers that show bifurcation. He considers that the undivided descending fibers are those for pain, the thick undivided ascending fibers, with the divided fibers for both nuclei, the fibers for touch. Windle's theory will explain why, in lesions of the spinal trigeminus root, there is often a slight loss for touch in addition to the loss for pain and temperature. Stopford and Gerard, on the basis of many cases of occlusion of the posterior inferior cerebellar artery, concluded that the spinal trigeminus root carries only fibers for pain and temperature. Whether twigs from the facial nerve end in the spinal trigeminus root, as has again recently been asserted by Hunt, Souques, Bandomir and Freeman, has not yet been definitely established. According to Freeman, the caudal trigeminus root nucleus in higher vertebrates usurped some skin areas that in lower vertebrates are innervated by the branchial nerves, especially the facial, glossopharyngeal and vagus nerves.

There is no unanimity of opinion concerning the relation of the cerebellum to the posterior fascicular nuclei. Yoshida found that neurites from the cells of the nuclei of Goll and the median part of the nuclei of Burdach pass over only in the medial fillet. This assertion needs further investigation, for with Marchi studies, degenerations are found in the cerebellum in fibers coming from the medial posterior funicular nuclei. These nucleocerebellar fibers, which according to Winkler are derived from the small cells, unite with posterior funicula elements. It is possible that with them are mixed endogenous spinal fibers from the deeper area of the cord. Yoshida thinks that Monakow's nucleus has a cerebellar association by way of the formatio reticularis. Winkler denies this. Through the corpus restiform also pass the cerebellipetal fibers of the spinal cerebellar tracts, of Gudden's nucleus, of the restiform body and of the opposite olive, while the

connection of the nuclei arcuati with the cerebellum, according to Winkler, is largely over the raphe through the base of the fourth ventricle and the stria medullaris of the fourth ventricle. The dorsal cerebellar tract appears to end mostly in the homolateral side of the vermis and to a smaller extent in the contralateral side. Brun thinks that they end in the anterior and posterior third of the vermis. Beck observed in cats that the tract ends on the homolateral lobulus centralis, culmen, declive, pyramis and lingula, less in the tuber and none in the uvula and in the lobus paramedianus of the hemispheres. Winkler's opinion is that Flechsig's tract ends in the cortex of the vermis anterior to the fissura prima, while Gower's tract ends in the lateral cortex of the lobus posterior behind the fissura secunda. The type of ending is also under discussion. Cajal thinks that the spinocerebellar fibers end as the mossy fibers around the granular cells, while Jelgersma, Brouwer, Marburg and Coenen are inclined to consider them as the climbing fibers around the Purkinje dendrons.

The intrapontile sensory nuclei have been considered the end-station of proprioceptive trigeminus fibers. Förster and Davis consider that fibers for deep sensibility pass through the facialis intermedius, through the geniculate ganglion and, to a lesser degree, through the portio minor of the trigeminus ganglion cells. The hypoglossus also carries proprioceptive deep sensory fibers. It has not yet been established that the pontile trigeminus nucleus has a direct connection with the cerebellum. Marburg believes that a part of the tractus nucleocerebellaris joins Spitzer's lateral tectal bundle, which passes from the fibraecommunicantes trigemini into the brachium conjunctivum; he calls it the fibrae trigeminicerebellares. The rôle of the mesencephalic trigeminus root as a proprioceptive system is not yet certain. Nicolesco considers it as similar to Clarke's column. Wallenberg still holds that the mesencephalic trigeminus root contains centripetal tracts and that these cells come phylogenetically from the deep layers of the roof of the mesencephalon, therefore from elements from which the tectobulbar and tectospinal systems originate. Kohnstamm considers that the locus coeruleus in lower animals is homologous with the sensory end nucleus of the ramus ophthalmicus. According to Kure, some of its cells are identical with the mesencephalic trigeminus root cells.

Allen affirms the topographic division of the tractus solitarius—intermedius fibers are found laterally, vagus fibers medially, and between them glossopharyngeal root cells. Only a few of its fibers cross into the commissura infima. Nordkemper observed a spinal ganglion type of structure in the jugular and nodose ganglia, therefore neither can be looked on as a relay station for parasympathetic vagus fibers. The viscerosensory bulbar centers are considerably reduced in mammals and in man.

All cranial nerves carry afferent autonomic fibers, but their exact location and ending is not known.

In the medulla and pons, the spinothalamic and spinotectal tracts lie ventromedial to the spinal trigeminus root. The ventral lateral fibers are from the lower part of the body, the dorsomedial fibers from the upper part of the body up to the fourth cervical segment; the more dorsomedial crossed fibers of the posterior horn are from the upper cervicals. The latter form Spitzer's lateral tectal tract, which dorsomedially joins the spinal trigeminus root.

There is also a functional division of the exteroceptive tracts in the medulla and pons. Clinical observations indicate that the fibers for pain and cold run lateral to the fibers for heat, and that these come near the tactile fibers.

It is characteristic for all the secondary exteroceptive tracts that frontally their fibers rapidly diminish. Only a few are left at the frontal pons area, while the numbers of fibers from the secondary proprioceptive system remain relatively stationary. At the same time there are individual variations; in some the fibers may reach the midbrain. Part of the fibers end in the nuclei of the formatio reticularis where a tertiary tract begins. The number, position and size of these centers varies. Kohnstamm and Quensel have shown that there are large and medium sized cells, lying central in the formatio reticularis, from the midbrain

down as far as the facial nucleus, at which end some secondary sensory tracts, some neurites of which, as reflex fibers, run to the motor coordinating nuclei and others run frontally as tertiary sensory fibers. The reticularis nuclei are not only motor reflex centers; not only do they transmit a particular type of stimulus, but they are able to receive stimuli of different qualities from different tracts; a combination of quality sensitiveness is possible not only in the higher sections of the central organs and in the brain cortex, but also in the caudal medulla oblongata and perhaps even in the cord. Naturally this is subject to many individual variations.

In man, the spinotectal and quintotectal fibers are few in number, but it appears that the anterolateral fibers have an ending in Edinger's nucleus praetectalis which corresponds to D'Hollander's nucleus posterior thalami. This nucleus forms the transitional ganglion from the diencephalon to the mesencephalon and in addition forms the passageway for the corticotactile elements and the nucleus of origin for descending tracts.

The secondary proprioceptive tracts come from crossed interolivary fibers derived from the posterior column nuclei. After the crossing, the fibers from Goll's nuclei lie dorsal to those from Burdach's nuclei. Whether they retain this position up to the frontal pole of the inferior olive cannot be said with certainty. It is not known how the fibers of the lemniscus medialis are arranged in the pons. It appears that the medial part stands in relation with the sacrococcygeal area. Although the greater part of the lemniscus medialis, contrary to the spinal thalamic tract, reaches to the interbrain, yet it gives up a considerable number of fibers before reaching this point. Some of the fibers from the medial part go to the substantia nigra. Castaldi called attention to the importance of this relation, for in this way stimuli reaching the substantia nigra from the striatum, opticus and mammillary bodies (hence olfactory), meet with proprioceptive ones.

In addition to the substantia nigra, the nucleus ruber may be looked on as a main station for fibers coming from the lemniscus medialis of the mesencephalon. Elements of the lemniscus medialis pass over also into the brachium conjunctivum. Similarly, fibers from the brachium conjunctivum, after they cross, pass into the lemniscus medialis.

Of principle importance is the passing over of the most medial lemniscus medialis fibers into the pedunuculus corporis mammillaris, forming a proprioceptive connection between the lower sacral segments with the corpus mammillare and therefore with the hypothalamus.

The brachium conjunctivum gives off some fibers in the formatio reticularis of the same side and some fibers, after crossing, descend as far as the inferior olive, but the largest part end in the opposite red nucleus. The remaining fibers, according to Allen, end in the opposite medial part of the ventral thalamic nucleus, and cross backward over the massa intermedia into the homolateral side in the medial nucleus, in the zona incerta, formatio reticularis thalami and in the regio subthalamica, after giving up fibers to the formatio reticularis of the mesencephalon, to the oculomotor nucleus and, according to Winkler, also to the trochlear nucleus by way of the posterior longitudinal bundle. Wallenberg was able to follow fibers of the brachium conjunctivum, in the rabbit, after crossing, into the nucleus ruber, the oculomotor nucleus, the nucleus supramammillaris, the medial and ventromedial thalamic nuclei up to its frontal pole; also, after crossing through the massa intermedia, into the homolateral medial ventral thalamic nucleus and also most frontally, on its dorsal border, near the nucleus anterioris. The red nucleus is also connected with the ventromedial thalamic area. The small cells, however, received fibers from the brain cortex and the basal ganglia, the largest number of of which are centrifugal in character. Fibers from the red nucleus connect also with the nuclei profundi mesencephali, forel's field, the subthalamus and the hypothalamus.

It is difficult to follow the viscerosensory tract above the spinal cord, since the fibers in large number are apparently nonmyelinated; also they become considerably reduced by giving off fibers to the medulla, pons and the mesencephalic radicular

nuclei. In the brain stem, the part of the anterolateral tract may be looked for in the formatio reticularis, dorsal to the lemniscus medialis.

The secondary tract of the bulboviscerosensory nuclear column comes from the dorsal part of the spinal trigeminus root nucleus and the intrapontile quintus nucleus; also from the nucleus of the fasciculus solitarius with its frontal extension. After injury to the intrapontile trigeminus nucleus of the rabbit, Wallenberg was able to follow a homolateral as well as a crossed fiber bundle which gave off fibers to the quintus nucleus of the mesencephalon and to the nuclei of the formatio reticularis pontis and mesencephali; only a few fibers reached the centrum medianum of the thalamus and the central gray matter of the third ventricle. The connection of the Lemniscus medialis to the substantia nigra most likely contains secondary visceral fibers. According to Economo, it is plausible that the substantia nigra contains a complicated central apparatus for chewing and swallowing. V. Monakow saw a curved bundle of fibers coming from loosely lying large cells ventral to the tractus solitarius and from the substantia gelatinosa, which crossed dorsal to the posterior column nuclei and formed a new part of the lemniscus—"the vagoglossopharyngeal lemniscus"—which apparently runs to the thalamus and indirectly to the cerebral cortex. This new lemniscus, according to Monakow, should serve the sensory innervation of the nasopharynx, larynx and bronchi, and perhaps also that of taste. Allen observed also in the guinea-pig a secondary tract coming from the frontal nuclei of the tractus solitarius, which apparently ran in the lemniscus medialis or near it; he considered that this was a general viscerosensory tract.

It is regrettable that the course of the secondary viscerosensory tract is not known, especially since in lower vertebrates the connection of this tract with the hypothalamus was established long ago.

It can be said with certainty that the secondary sensory tract in the interbrain ends in the ventrolateral nuclear groups of the thalamus, in Forel's nucleus arceatus, in the centrum medianum of Luys and in the borderline parts of the nucleus medialis up to the central gray matter. According to Környei, the caudal part of the ventrolateral nucleus is the borderline for the lemniscus medialis; the middle part, for the radiate rubroconjunctivothalamic from the nucleus ruber and the brachium conjunctivum; in the frontal part the pallidothalamic fibers end. It is possible to separate, within the thalamus of mammals, a phylogenetically old ventromedial part, which is the end-station largely for the octavolateral, cerebellar and other proprioceptive tracts. This can be separated from a phylogenetically more recent dorsolateral part, the neothalamus, which in birds and some other animals belongs mainly to the mesencephalon; it may be considered as the end-station for somatic sensibility, the exteroceptive tracts. Wallenberg found that the end-stations of the somatic sensory tract within the dorsal and lateral thalamus of mammals follow the law of excentric ordination of long tracts, the fibers that come mainly from the cord end mainly in the ventrolateral part of the nucleus lateralis, the secondary trigeminus tract of the cadual medulla oblongata end in the dorsomedial part of this nucleus and in the nucleus arciformis, the fibers from the more frontal medulla oblongata part in the centrum medianum of Luys. On the ventromedial and dorsomedial borders, which are areas for extroceptive fibers, there are found in mammals, birds and some other animals, transitions in the end-stations for the octavolateral, cerebellar and other propioceptive tracts.

In the ventromedial nuclei of the ventral thalamus enter lemniscus fibers, largely from Goll's nucleus, over the lamina medullaris externa, while the fibers from Burdach's nucleus end in the middle, less on the lateral part of the nucleus ventralis. Frontally to the end-station of the fibers coming from Goll's nucleus end the fibers from the brachium conjunctivum, with the rubrothalamic fibers in the medial part of the ventral nucleus as far as the frontal pole. Fibers from the brachium conjunctivum cross through the massa intermedia and end in the homolateral medioventral thalamus nucleus up to its frontal pole. The tendency to bilateral ending is characteristic of cerebellar and vestibular fiber systems. The spinothalamic tract, after giving off fibers to the nucleus reticularis, can be followed

to the lateral part of the ventrolateral thalamic nucleus. Laterally it is bordered by the medial border of the corpus geniculatum mediale. Dorsomedial to this spinal tract end fibers coming from the ventral and caudal part of the end nucleus column of the spinal trigeminus root, as they also do in the dorsolateral part of the ventral nucleus and in the nucleus arcuatus. Frontal parts of the spinal trigeminus root nuclei send their secondary fibers to the centrum medianum—dorsal and proximal parts for the innervation of the lips, tongue and mucous membrane of mouth pass chiefly over the lamina medularis interna in the nucleus medialis as far as the central gray matter, in the frontal thalamus area and also to the dorsal border of the ventral nucleus. The association of exteroceptive, proprioceptive and also partly interoceptive quintus tracts in the centrum medianum, and its medial, and especially ventral, neighborhood gives importance to this area as a center for mimic, and its connection with the vasomotor and other autonomic systems. It is also possible that secondary tracts of the sensory vagus and glossopharyngeus end in the medial dorsal part of the centrum medianum or in the median thalamic nuclei as far as the central gray matter of the ventricular walls. So far no answer can be given to the question as to where the tertiary tract from the nuclei reticularis of the medulla oblongata, of the pons and of the mesencephalon ends; these are secondary centers for a large part of the exteroceptive sensory system.

In the interbrain, the ending of the proprioceptive system in its larger sense, including fibers from the brachium conjunctivum and the rubrothalamic fibers, differs from that of the exteroceptive system. While the exteroceptive system ends mainly in the thalamus, and while its end nuclei have comparatively slight connection with the striopallidum and mostly with the brain cortex, the proprioceptive system has close connection, direct and indirect, with the hypothalamus and with the pallidostriatum, over the thalamic end nuclei. Ferraro saw, in the dog, especially medial parts of thalamus entirely independent of any neo-encephalon. It has been mentioned that lemniscus medialis fibers from the sacral part of Goll's nucleus enter the corpus mammillare over the peduncellus corporis mammillare. Near to it run fibers from the end pole of the lemniscus medialis, especially from its median part, into the hypothalamus in the lateral mammillary nucleus, and in the zona incerta and its neighborhood; they reach also into the substantia nigra. A large number of fibers from the brachium conjunctivum enter the nucleus supramammillaris, and in the gray matter of Forel. Greving described as a fasciculus thalamo-infundibularis, tractus supra-opticus superioris, and tractus paraventricularis cinereus, connections between the medioventral thalamus with the nuclei of the tuber cinereum, which among other things assists in connecting the centripetal tract between the thalamus and hypothalamus. In addition, the lower thalamus connects with the nucleus of the tuber through the tractus supra-optico-thalamici of the nucleus supra-opticus. The relation of Forel's bundle, H_1 is yet uncertain. Many authors consider that it connects the pallidum with the thalamus.

The relation of the thalamus to the striatum and pallidum is phylogenetically very old. Although the striothalamic and pallidothalamic fibers are by far in larger number, there is no doubt of the presence of thalamopallidal and thalamostriatal fibers, which come especially from the medioventral and ventral thalamic area—again, end-stations for proprioceptive tracts. Cécile and Oskar Vogt saw fibers coming from the ventromedial nuclei of the thalamus (near the hypothalamus) which reached the striatum and pallidum. Marburg described also thalamostriate connections coming from the lateral nuclei over H_1. Pollak and Jakob described striopetal fibers coming also from the dorsal part of the ventrolateral thalamic nucleus. According to Foix and Nicolesco, the fibrae thalamolenticularis pass from the middle part of the thalamus to the nucleus lentiformis through the lower part of the internal capsule, the fibrae thalamocaudate fibers from the frontal lower thalamus to the caudate, through the upper limb of the internal capsule, while the ansa lenticularis and the bundle H_2 are connected with the ventromedial thalamus and the neighboring area of the regio periventricularis. Ernest Sach's observations are important. After producing lesions in the inner parts of the thalamus in the

cat, he could find no connection with the cortex coming either from the small cells of the centrum medianum of Luys, or from the nucleus arcuatus. Ferraro found, after removing the brain cortex of the dog, that especially the middle part of the thalamus was independent of the neocortex. Wallenberg cannot say whether there may not be a kind of phylogenetic shortening in such a way that centers, which in lower animals are still found in the midbrain and are connected with the thalamus through tectothalamic or mesencephalo thalamic fibers, are in mammals located in the caudal part of the thalamus and therefore are connected intrathalamically with the frontal nuclei.

The relation of the thalamic nuclei to the brain cortex is known through the work of Monakow. The centripetal, thalamocortical connections can be considered as the transmittors of sensory stimuli from the thalamus to the pallidum. Meier Müller affirmed Monakow's observations. Mingazzini holds that the frontal part of the dorsal thalamus stands in relation with the lobulus paracentralis; the caudal part with the lobulus praefrontalis, parietalis and operculum rolandicum; the frontal part of the nucleus ventralis anterior with the opercularis of the second and third frontal convolutions, gyrus praecentralis, plus operculus; the nucleus ventralis with the gyrus supramarginalis and the posterior half of the gyrus postcentralis; the frontal pole of the nucleus lateralis with the prefrontal convolutions; the caudal with the inferior parietal, and the middle half with the gyrus praecentralis and the upper part of the gyrus postcentralis.

After removal of the cortex there are severe cell changes in the various thalamic nuclei with the exception of the ganglia habenulae, the nucleus praebigeminalis and the ventral part of the geniculatum externum. The nucleus parependimalis remains intact.

Minkowski, from experiments on monkeys, has established that all neocortical convolutions possess a corticopetal and a corticofugal associative, and in nearly every case also a commissural fiber system. Further, that the postrolandic region receives its corticopetal fibers from the posterior third of the dorsal lateral nucleus, from ventralis *a*, ventralis *b*, and the zona reticularis: while the regio praerolandica is corticopetally connected with the dorsolateral, ventrolateral and ventromedian nuclei, also with the corpus Luysü and the zona reticulata. The parietal region has relations with the dorsolateral nucleus, with ventral *a*, *b* and *c*. To the gyrus angularis come fibers from the pulvinar, from the ventralis anterior, nucleus anterior and median *A* and also from the pallidum. The regio frontalis receives fibers from the dorsal lateral nucleus, the anterior part of the ventral nucleus, nucleus anterior and median nucleus *A*.

According to Wenderowicz, the course of the sensory projection tract from the thalamus to the cortex is through the posterior third of the internal capsule to both central convolutions and not to the gyrus supramarginalis. In the anterior central convolution the fibers are mixed with the motor fibers.

Economo holds that the "tactile radiation," that is, the sum of the fibers that go to the postcentral area, come largely from the central and ventrolateral thalamic nuclei through the internal capsule. Anteriorly, close to the pyramidal fibers pass the "tectoradiation" fibers for the ventral part of the centralis posterior, over the upper border of the nucleus lentiformis and above in the corona radiata of the operculum to the lower part of the postcentral area. The tactile radiations for the upper part of the postcentral area pass through the reticulolenticular capsule division, close anteriorly to the visual radiation, and rise anteriorly and above to the upper part of the postcentral area. A similar course for this tract is given by all modern authors. Pure skin sense, that is, the sphere of touch in its narrower sense, Economo localizes in the anterior wall, the muscle sense in the posterior wall of the postcentral area, it perhaps reaches to the anterior part of the gyrus supramarginalis. The nearer the lesion is to the sulcus rolandi, the more the superficial sense, the skin sense, will be affected. The more the lesion is to the back of it, the more the sense of position and movement will be involved. It is possible that the koniocortex, P. B. 1, is the exclusive and only part of the cortex in which the primary stimuli of all tactile qualities enter and thus reach consciousness as a simple sensation element; from here through the combination of such

sensation elements and through the mediation of other parts of cortical sensations appear then to localize sensations in other parts of the postcentral area. The theory of psychic localization is not yet established. According to Goldstein and Monakow, psychic processes are the foundation of the cortex as a whole.

Goldstein considers that the sensory cortex center is postcentral and the borders the parietal. He considers that muscle sense is localized in the gyrus supramarginalis, gnosis for touch-pressure mainly in the postcentral convolution, stereognosis in the gyrus supramarginalis and angularis and to some extent in the occipitalis.

The topography of the postcentral area somewhat corresponds to that given by Vogt and Förster for the precentral area. From the dorsomedial and caudal in frontal and ventrolateral direction follow the genito-anal zone, toes, foot, lower and upper leg, hip, trunk, upper and lower arm, hand, fingers, neck, mouth, face, tongue and taste. The medial parts are bilaterally supplied. Within the sensory cortex, pressure, pain and temperature sensations are apparently in the forepart of Brodmann-Vogt fields *3a*, *3b* and 1. In the same area, posteriorly, in field 2, is the area for pressure and movement sensations, and for stereognosis, in field 2 of the parietal cortex. Förster does not believe that there are separate cortical areas for the individual sense qualities, but rather that the same areas contain different layers for the different sense qualities. The basis for this hypothesis can scarcely be proved anatomically. On the other hand, there is enough structural similarity between the caudal precentral area and the sensory cortex area to warrant the assumption that the prerolandic area partakes in cortical sensation.

There are many questions to which Wallenberg finds no answer. Are the individual cortical fields sharply separated or do they show transition? Does the mosaic area represent a mosaic of consciousness and subconsciousness? Are there on the borders of the sensory fields narrow parasensory zones with large pyramidal cells in layer 3 *a*? Do the latter perhaps send axons which serve as adjusters of the same stimuli? Is the transition to the upper parietal at the area praeoccipitalis and peristriata a sudden or a gradual one? May the sixth layer still be considered as an entity or does it break up into two separate strata? What significance is there to the different grades of nucleation in the primary tactile sphere and, through these conditional individual differences, in the position and sharpness of the border?

Of principal importance is the fact that the side wall of the gyrus is largely the place for receiving the stimuli and for association, while in the summit appear more the minor efferent laminae. As Economo expressed it, the walls receive the stimuli and the summit transmits them.

Sensory conduction ends in the cortex. Does the sensory system stop there? Wallenberg's question does not refer only to the association tract of the cortex or to the larger commissural system. According to him, the descending tracts from the cortex to the thalamus and other subcortical areas form the most important part of the sensory system. These tracts have their origin in Brodmann's sixth layer. The neo-encephalic small cells of the nucleus ruber receive fibers not only from the frontal lobes, but also from both central convolutions. Although, according to Flechsig and Dejerine, the substantia nigra receives fibers mainly from the frontal lobe, Flechsig also observed a descending cortical nigral tract coming from the opercular part of the central convolution. Flechsig observed corticothalamic fibers coming mainly from the central convolutions, from the first frontal lobe and its adjacent part of the gyrus fornicatus and less from the parieto-occipital area. Recent studies indicate that it comes from the larger part of the convexity. Oscar Vogt followed the fibers coming from the centralis anterior in the thalamic nuclei, designated by him V*a* 1, from the centralis posterior into the V*a*, from the cortex praecentralis into the nucleus M. A.

Tsunesuki was able to follow corticothalamic fibers from the caudal half of the second frontal lobe to the nucleus medialis, from the posterior part of the third frontal to the nucleus medialis *b*, the end nucleus of the secondary trigeminus tracts, from the remaining frontal brain to the nucleus lateralis and ventralis anterior and from the precentral areas to the tuberculum anterioris. Villaverdie

reports on the corticothalamic relations from the motor cortex to the anterior thalamic nuclei need further investigation. Minkowski was able, in the monkey, to follow from the regio praerolandica, aside from the pyramidal tract and fibers to the pons, also fibers to the substantia nigra, to the nucleus ruber, to the zona incerta, and also to the caudatus and pallidum. Aside from the association fibers, the regio postrolandica sends fibers to nearly the same end-points as the anterior central area. The regio frontalis stands in a similar corticifugal relation with the striatum and subcortical parts as far down the cord as the regio praerolandica. Minkowski substantiated that all convolutions, at least those of the convexity, possess, with perhaps few exceptions, corticopetal and corticifugal projection fibers, although they may differ in quantity also in intracortical and extracortical association and commissural fibers. This established the existence of a corona radiata for all areas of the human cortex.

Winkler differentiated three groups of parietopontile fibers; one contains entirely collateral pyramidal fibers to the neighboring pontile nuclei; the second group ends in the ventromedial, most caudal pontile nuclei and partly cross; the third group unites the parietal area with the homolateral nucleus peduncularis along the entire expansion of the pons.

What is the function of the corticifugal fibers that go to some of the thalamic nuclei and which were found to be secondary or tertiary conduction paths? Head and Holmes saw in them, as well as in the corticotegmental tracts of D'Hollander, inhibitory fibers which inhibit excitability of the thalamic cells, similar to the function ascribed by Wallenberg to the corticospinal elements in the posterior column, which should inhibit the excitability of the homolateral posterior horn. Förster, as well as Goldstein, in explaining the hyperesthesia in lesions of the thalamus, assumed a striatothalamic inhibition, with the pallidum as the efferent part and the afferent part in the thalamus, or it reaches the pallidum through the thalamus. On the basis of clinical experience as well as from studies of comparative anatomy, Wallenberg has reached another opinion. To him the corticothalamic and the corticometathalamic fibers, as well as most of the other corticifugal systems, are nothing else than centripetal sensory tracts with the function of sensitizing sensory centers, primary, secondary or tertiary; to make them more capable of receiving the stimuli, to affect a kind of accommodation such as is manifested in every act of attention. Similar centrifugal sensory tracts are observed in the opticus, in the olfactorius and in the vestibularis; and in bony fishes the well known olfacto-optic and the bulbo-optic fibers, as well as the trigeminal connection with the parolfactorius centers in birds, may have origin in other sensory nuclei and centers. Weizsaker stated that only physiologic analysis divides centripetal sensory and centrifugal motor processes. Biologically, it is mixed sensory-motor process. No sensation and no perception takes place without an active, quasimotor factor.

The Divisions of the Tactile Sense. Dr. M. von Frey.

By the term tactile sense Frey has in mind the influence it exerts on all afferent nerves in the spinal cord and in analogous cranial nerves. How many types of afferent nerves are there? At what place are their receptors to be found and what causes them to be set into excitation? From the work of J. Boeke and his school it appears most likely that the nerves nowhere end freely in the tissues, that they enter the cell protoplasm, and they either receive or transmit stimuli. In the case of the former, one is dealing with transformers, so called, that is, arrangements which supply the reforming of the outer stimuli into nerve excitation. The nerves break up at Boeke's periterminal network, pass through the cells and reach over the cell border. This apparently is the connection of all nerves at the periphery. The question concerns the stimulation of isolated nerve endings and their specificity.

Pressure sensations are readily isolated and are therefore more readily open to investigation. There are two types of receivers of pressure sensation. On the hairy portion of the body they take the shape of basket-like networks which sur-

round the hair follicle at a line about its upper and middle third; on nonhairy surfaces, Meissner's bodies act as the receptors. Both types show great sensitiveness to displacements of the skin, rapid adaptability, lack of after effects, nonsensitiveness to chemical influences and highly developed topical differentiation. Aside from pressure sensation they may also be excited by touch, buzzing and tickling, which are to be considered as modifications of pressure sensation. The number of pressure senses in the body, according to Frey, is at least half a million.

A second component of the tactile sense is the sensation of cold. The end-organs are found generally in places of the body where there are pressure sensations. Sensation of cold appears when there is a rapid lowering of the temperature of the skin; slow changes are not observed, the nerve endings having time to adjust themselves to the change without being excited. High temperatures of from 40 to 50 C. (104 to 122 F.) are also effective and according to the location are perceived as cold. This is a paradoxic stimulus, as yet not much investigated. The sensitiveness for rapid stimuli changes in favorable cases amounts to a half degree (E. Gertz, Putter).

There are areas in which nonpainful temperature stimuli are perceived as cold. The conjunctiva, cornea and some parts of the genital area belong in this group; heat stimulation is not perceived in those places. Touch and pressure are also missing in these areas. This will tend to prove the competence of the receptors.

These receptors do not show any unusual makeup. W. Krause found them to be the so-called end-bulbs. They are not for pressure sense, since those already described are lacking here. They are rather to be considered as organs for the sensation of cold. H. Strughold, by straining the living eye, was able to prove this assertion.

The study of the cornea gives interesting results. It is well known how sensitive it is to pain; the margin around the border is also sensitive to cold. In this marginal area, there is a special subepithelial nerve apparatus composed of thick glomerule-like demyelinated fibers. These may be looked on as receptors for cold stimuli. Another place in which Krause and other investigators have found the terminal bulbs is in the glans penis; there, in addition, the so-called genital corpuscles are also found subepithelially. They resemble greatly the terminal bulbs (and therefore many authors consider them enlarged bulbs). It was shown that the terminal bulbs, especially the genital corpuscles, go topographically together with sensitiveness for cold.

At present the receptors of cold stimuli of the remaining body surface are not known. All that can be said about them is that they are comparatively superficial. When a large skin surface is made numb with cocaine by electrosmosis, the sensitiveness for cold disappears after itching and pinprick have disappeared, and before that for heat and pressure. When the numbness disappears, sensitiveness returns in reversed time order. In the upper layer of the corium A. Ruffini has described nerve endings which he designates "flochetti papillari"; they resemble terminal bulbs, but are of more slender structure and contain thickly united nerve fibers.

Here, as in the case with pressure sensation, one must be satisfied with the conception that a given sense quality may be united with more than one form of nerve ending. At the same time, the finer structure, as well as the particular service, of the endings is not known; this can be said for all the tactile sense qualities. For the same reason it is not possible to draw conclusions from the configuration of a receptor in regard to its function.

While something more definite can be said for receptors of cold, knowledge as regards the receptors for heat is less certain. They lie more deeply than those for cold and are more sparsely spread over the skin. They lie in the middle layer of the corium; some perhaps even deeper down.

The two types of temperature sensations differ from one another not only by their form and depth of position, but also in surface distribution. Cold receptors are about twelve times more numerous than those for heat. The former may be present when the latter are absent. They also differ in their rapidity for adaptation and in differentiate intensive and spatial threshold; the receptors for cold are capable also of paradoxic stimulation, as has been mentioned.

Receptors for pain are better known, at least those that have to do with itching and pricking. Their position is rather superficial. It was mentioned that in numbness preceded by electrosmosis this pain sensation is affected first; it is also the last to return after the numbness disappears. The smallest drop of corrosive substances, when brought into contact with the skin, causes pain exclusively in the form of itching and burning, apparently because the concentration for stimulation reaches only within the epidermis; when it reaches the more fluid corium it becomes diluted. Very delicate mechanical and electric stimulations produce itching and pricking, while at the same time their pressure is not felt. On the cornea, aside from the narrow border mentioned, any kind of stimulus will produce only a pain sensation and the stimulus threshold is unusually low.

This indicates that one must consider as receptors the nerve fibers that enter the epithelial layer regardless of their thickness: they end freely and are not covered with a capsule.

The faculty for the excitation of pain is not limited to the nerves of the epidermis. Pain may develop in nearly every tissue although it may differ in degree and kind. It is found in the blood vessels, in the perimysium and peritendinium and in other places. It is not known whether the different kinds of pain labeled under various names differ from one another only in a formal way, that is in space and time, or whether different elementary painful stimuli must be assumed. Dull, heavy, burrowing pain cannot be elicited on the skin surface.

The appearance of pain is the result of a chemical change in the tissues. This was proved by changes in concentration, in reaction, in ion equilibrium, and in the appearance of different substances in the tissue fluids. To the latter belong the inflammatory products. It was maintained that pain is the result of a summation of different kinds of stimuli. This opinion was based on the comparatively long latent period of pain. When the stimulus is accompanied by heterogeneous effects, as pressure and temperature sensations, and then is followed by pain, it may well seem as if the former passes over into the latter. When delicate stimuli are applied and specific areas for mechanical and thermal stimuli are avoided, especially when the stimuli are applied in places which possess neither temperature nor pressure sense, one is able to obtain pain as a first and only result. A sensation of heat appears only when a point for heat sensation is touched accidentally. Some time after a drop of glacial acetic acid is applied to the skin there develops a pure sense of pain in the form of itching and burning, and no other sensation. The latent period of from fifteen to thirty seconds is not a summation; it is an expression of the slow penetration of the corrosive substance in the resisting epidermis. Mechanical stimuli, individually too weak to excite pain, may do so after sufficient repetitions, since they damage the tissues. The pain when walking with a blister on the foot is not caused by the repeated action on the pressure sense, but is the result of the pressure or rubbing of the shoe which causes inflammatory changes.

Pain, like any other sensation, is subject to localization; it is well defined at least as far as surface pain is concerned.

Sensations of a not painful character can be elicited from the tissues under the skin. This is known through clinical and experimental observations which do not always agree in minor details. This is true for the so-called deep pressure sensibility which is double that for the surface, yet with a lesser sensitiveness. It appears when the surface sensibility is removed either through paralysis or through artificial numbers. Mechanical stimulation in such areas becomes effective after an increased expenditure of force. But it does not develop a new constant threshold; it depends only on the size of the nonsensitive surface, provided that the stimulus is applied in the middle point of this area and not at its border. A benumbed area of 100 sq. cm. requires a stimulus 1,000 times greater than that required normally. It is almost impossible to prevent deformation of the skin from reaching out to the border of the benumbed area.

The perception of movement and position is different. The sense of pressure acts as an auxiliary, the collaboration of which cannot be excluded, but it is not

the chief thing; the deep receptors may even decide against it. Frey here described an experiment which tends to prove this statement, that it is the force or the tension sensation of the muscle and not the pressure sense which gives results.

What arrangements enable the muscle to tell the degree of its tension? This as well as the question of muscle tone and reflex is of the highest importance. Since the muscle spindles have been proved to be receptors for the latter, it is most likely that they also serve as receptors for muscle sense.

The musculature is capable at all times of giving exact information regarding the degree of its tension, as well as the position of a joint with its momentary changes in space. That such arrangements are present one learns from the posture reflexes which bring the tonus of the muscles into harmony with posture.

The pressure sense offers some contribution since the form and tension of the skin constantly change with each change in the position of the joints. Also in all cases in which the head changes its position in relation to the radius of the earth, or when it is turned, the labyrinth becomes active. But it has been shown by Magnus that in addition to these receptors there are also others lying in the deep tissues that assist in this activity. Experimental investigation indicates that the changes in the connective tissue joint capsule, and the displacement of the tendon against the peritendon and its neighboring parts, bring about the perception.

In the connective tissue are found egg-shaped capsulated bodies partly of microscopic dimensions, which were named after Vater-Pacini and Golgi-Mazzoni. They are supposed to arrange those stimuli which give the information concerning the position of the joints and the posture reflexes not derived through the labyrinth. It may therefore be proper to designate the impressions evoked through these receptors as posture sense or perception.

It is characteristic for the power and posture sense that they cannot be separated into components. In this respect they differ essentially from the sense perception of the skin in which the individual impressions can be studied, such as space, weight, temperature, etc. Only by eliminating artificially some individual components is it possible in the former to gain some knowledge.

A still greater difficulty is encountered in attempting to explain the bodily sensations. It is clear that hunger, thirst, a sense of well-being, repulsion and tiredness, excite afferent nerves within certain organs and that organ systems are affected to a considerable degree. But it is not altogether certain that these combined impressions thereby exhaust the factors. It is more likely that in connection with the local excitation, changes take place in the larger of regulatory functions, in the circulatory and breathing mechanisms, in metabolism, in heat regulation, in muscle tonus, etc., which also incite afferent nerves and thus contribute to the general picture. Thus experiences develop which may justly be described as "common feeling." To find the individual components, to prove their kind and value is a task in which this present investigation is not of great help. It can be said with certainty that, essentially, one is dealing with complex sensory elements, because the common or generalized sensations appear and disappear at the same time as the individual sense sensations do, as something foreign to the psychic process. In this respect they are entirely different from mental sensations, such as pleasure, worry and anger.

Little is known concerning the nature and character of the different fibers, the relations between them in the nerve stem and with the different efferent fibers. They reach the spinal cord partly through the somatic and partly through the autonomic path. A sharp functional division does not seem to be present. It is noteworthy that the dull pains from the intestine come through the autonomic system.

A decided topographic ordination of the afferent tract which possesses also functional importance is first found in the spinal cord and in the brain, in the gray masses of which the exciting process assumes shape and represents conscious phenomena.

THE TOPICAL DISTRIBUTION OF SENSORY DISTURBANCES IN LESIONS OF THE SENSORY TRACTS AND CENTERS. DR. OTTO SCHAWB.

The size of the area and the type of disturbance of the different sensory qualities affecting a body area depends on the location of the lesion in the systems which serve the different sensory qualities. From the extent of the disturbed sensory area and from the type of the disturbance of the different sensory qualities, it is possible to draw a conclusion as to the disturbance in the nervous system. Head's views as far as the topical nature of the different qualities are concerned are as follows: After a peripheral sensory nerve is sectioned, there is found in the distribution zone a small area of complete anesthesia, the extent of which varies individually. To this anesthetic zone there is added a zone in which there is a marked disturbance in touch, in differentiation between warm and cold between 20 and 40 degrees of temperature, as well as appreciation of dual stimuli by two points. Förster took exception to this view. According to him, the zone adjoining the one of total anesthesia not only shows a disturbance in discrimination of temperature between 20 and 40, but the disturbance also exists in maximal cold and warm stimuli and pain is diminished also in the same area. Schwab is in perfect agreement with Förster.

After sectioning a peripheral main stem the author can differentiate:

1. A so-called autonomic zone, in which all the qualities of the peripheral nerve are lost, as tested with maximal stimuli; a zone therefore, which, as far as the sensibility of the skin is concerned, is supplied by one definite sensory nerve; a zone which differs individually very markedly, and may, especially in the radial nerve, be missed entirely.

2. To this area of complete anesthesia is added the so-called mixed zone, in which there is partial sensory disturbance — pain sensation is not lost, touch as tested with cotton, heat and cold, mostly for maximal temperatures, are lost; a zone in which fibers from neighboring nerves supply the sensation of pain. The boundaries of the tactile anesthesia in the mixed zone are mostly smaller than the area for the disturbance of heat; the disturbance for cold often shows the largest area, so that, to a lesser degree, neighboring nerves are also affected for these qualities. To determine the maximal distribution zone of a peripheral sensory nerve, it is necessary to cut all neighboring nerves and the area which is not completely anesthetic will determine the area of the peripheral nerve. The remaining sensibility, according to Sherrington, represents a defined nerve and furnishes information as to how far and the kind of qualities a particular nerve radiates to adjacent areas.

3. It is also possible to determine a "subsidiary zone." It is a maximal zone for sensation of pain which a particular nerve supplies to contiguous nerves.

The senses of position, movement and deep pressure belong to the autonomic area. When the ulnar nerve is cut they are found only in the joints of the fifth finger; when the median is cut the second and third fingers are involved; on cutting the peroneus, the radial, the crural, etc., distubance of position and movement are not observed. By total sectioning of many nerve stems disturbances of position and movement appear only in those parts in which the superficial and deep parts are totally anesthetic.

The principles enumerated concern only mixed nerve stems. A pure cutaneous nerve when eliminated is at times found to correspond with the anatomic distribution zone; the area is also at times anesthetic for light touch and temperature, while the entire area remains sensitive to stronger pressure. Disturbance of position is not observed.

Sensory disturbance from partial interruption of a peripheral nerve corresponds more or less, as far as extent is concerned, to the already described autonomic and especially the mixed zone. As for the sense qualities, the sensation of pain is not lost, touch and temperature disturbances cover the autonomic and mixed area, or tactile sensation may persist in the mixed zone and temperature be entirely disturbed. Again, pain and heat may be intact while the sense of touch is lost. Also, all the forms of sensation may remain intact and only the spatial differentia-

tion of the skin or the sense of movement and position be lost. A similar condition is found on the return of function of a sensory or mixed nerve. First the area of pain anesthesia becomes smaller, later the area for heat, then that for cold and last the spatial sensation of the skin. This corresponds with the observations of Head and Rivers.

Irritation phenomena, such as are observed in neuralgia — a sensation of dryness, crawling, formication, anesthesia dolorosa — in lesions of pure sensory and mixed nerves are localized essentially in accordance with the anatomic distribution; the boundaries are often ill defined and there is a greater predilection for the distal parts.

By eliminating a single spinal ganglion Petrén and Bergmark found that there may be disturbance in the pain and temperature sensation in the affected dermatome, while tactile sensation remains intact.

In order to establish the sensory disturbance by eliminating a spinal root, it is necessary to know the relation between the root and a definite skin area, the dermatome. According to Sherrington, the touch dermatome is generally larger than the pain dermatome. A trustworthy schema of the human dermatome does not exist. There is no reliable information concerning the size of the overlapping zones and no definite knowledge of the magnitude of each individual touch, pain and temperature dermatome. Förster's observation is that resection of a single root in man is not followed by any considerable sensory disturbance. After cutting two adjacent roots, there is nearly always some sensory disturbance in the area supplied by these roots; it affects mostly the temperature, or pain and temperature sense. After sectioning the second and third lumbar roots Förster noticed no sensory disturbance. After cutting three consecutive roots, he found only one case in which there was no sensory disturbance; in other cases there was always an extensive area of tactile anesthesia and analgesia. In the lower lumbar and sacral dermatome the overlapping is apparently much greater. The overlapping in man also shows much individual variation. When a number of neighboring roots are cut, the disturbance of touch and space takes in a smaller area than that for the disturbance of pain and temperature, and perhaps the area of thermanesthesia is somewhat larger than the area of analgesia. From these observations it can be stated that tactile sensation, deep pressure and deep pain of at least three successive posterior roots can be traced to one dermatome, and pain and temperature of at least two successive posterior roots to one dermatome. It can definitely be said that disturbances in sense of position and movement appear only when all the functions for the limb or joints are lost.

Irritation phenomena in lesions of the posterior roots (inflammatory processes, tumors, trauma, syphilis) especially pain, but also burning, crawling and formication, are localized either sharply on the appertaining dermatome or they radiate segmentally to neighboring areas. Pain may be present together with total anesthesia (anesthesia dolorosa) or with partial sensory disturbance (temperature and spatial), or sensory disturbance may be missing. It may also show different kinds of dissociated sensory disturbances. Pain and temperature sensation may be affected while tactile sensation is impaired; tactile disturbance takes in a smaller area than the disturbance of temperature; pain and touch remain normal and only temperature is affected, or all qualities remain normal and only the spatial sense of the skin is affected in one or more dermatomes.

Complete section of the cord results usually in complete anesthesia up to the level of the lesion, with the boundaries of tactile anesthesia also somewhat less than for pain and with the largest area for temperature disturbance. Even with complete section of the dorsal cord high up there still remains occasionally a dull uncertain pressure and touch sensation, for which, according to Förster, the sympathetic, the vagus and the phrenic nerves may be held responsible.

The sensory qualities of the anterior roots are not definitely decided. If this has sensory function at all it is only as an auxillary to a very dull pain sensation. Faradic stimulation over the central area of such roots develops, according to Förster, a sensation of pain in the area of the corresponding posterior root. Even here, however, there are many individual variations; sometimes such

stimulation will not develop any pain. Section of the cord at the first dorsal segment abolishes all pain in the internal organs of the chest and abdominal cavity; at the sixth dorsal eliminates pain in the organs in the abdominal cavity and in the pelvis.

Knowledge of disturbances of the posterior root rests largely on observations of syringomyelia, traumatic necrosis, stab wounds, and other injuries.

The topical distribution of a suppressed posterior horn embraces the dermatomes of the same side for pain and temperature sensations. The analgesia takes in all painful qualities, including deep pain and also the organs supplied. In syringomyelia and hematomyelia there are two main types of pain and temperature disturbance: (1) the segmental type; (2) the circular type. The segmental type takes in the dermatome, the posterior horns of which are functionless. The circular type is thus explained by Brouwer. Each posterior horn has an inner topography according to the body zone, in which the medial section supplies the most lateral part of the body, so that damaging the medial part of several posterior horns lengthwise (from the fifth cervical to the first dorsal) will result in circular pain and temperature disturbance of the hand. According to Förster, in addition to body area topography one must also assume different groupings of the elements in the cross-section of the posterior horn which serve pain, warm and cold sensations. Schawb cannot give these separate groupings; he can only state that, clinically, after injury to the posterior horns or its centrally-going tracts there is a dissociation between pain, heat and cold.

Irritation phenomena, especially pain, after stimulating a posterior horn embraces an entire body metamere. Consequently, all pains of the internal organs are localized so readily in the corresponding cutaneous dermatome of the same root or in the same segment which supplies the skin and the inner organs.

In lesions of the posterior column there are disturbances in the sense of position, movement, localization, stereognosis, force, pressure and vibration. The best method to determine the segment level of a posterior column lesion is to test by writing figures or numbers on the skin. The loss of that sense gives the height of the lesion.

According to Edinger and Wallenberg, the arrangement in the sensory decussation is such that the part for the arm lies ventrally and dorsally, and in order come the fibers for the trunk, leg and sacrum. In the fillet the area for the sacrum lies most medially, the lumbar and dorsal zones are lateral and that for the upper extremity is most lateral. Definite evidence for these topics are lacking.

The continuation of the anterolateral tracts, especially the spinothalamic tracts, is found in the formatio reticularis of the medulla oblongata, pons and pes pedunculi. A lesion in the formatio reticularis results in contralateral disturbance of pain and temperature. According to Marburg, the medial part of the formatio reticularis is for pain, the more lateral part for cold, and the most lateral for heat. Bergmark does not agree with this localization, but concedes that the fibers for pain conduction lie most medially. On the other hand, Wallenberg contends that the fibers for heat conduction lie more medially than those for cold and pain. All authorities are in accord that the first cervical segments are most medially situated; more laterally come those of the arm and trunk, and those of the lumbosacral areas lie most laterally.

The spinal trigeminus root, the substantia gelatinosa nervi trigemini corresponds, in regard to function, essentially with that of the posterior horn, the nucleus sensibilis nervi trigemini and the posterior column nuclei. The fibers from this trigeminus root to the nucleus spinalis nervi trigemini are analogous to the posterior root fibers which end in the posterior horn of the cord. The fibers coming from the radix spinalis trigemini and decussation correspond to the fibers coming from the posterior horns of the cord and cross to the anterolateral tract. The quality that these nerves serve is similar to those performed in the cord. The fibers coming from the nucleus sensibilis nervi cross over and lie dorsomedially in the leminiscus medialis. According to v. Solder, lesions of these fibers will cause a homolateral, onion-peel type of disturbance of pain and temperature in such a manner that a ventrodorsally ascending lesion of the spinal trigeminal

root will cause thermanalgesia in the temporal ear and chin line, then the head skin and forehead, then concentric spotlike areas on the side of the face, then gradually the upper jaw, eyes and nasal area, and finally the entire face including the tip of the nose; when the lesion is more dorsal it will lead to corneal anesthesia. In the aural area a few tactile fibers are mixed in, but the largest number of the tactile fibers for the trigeminus are affected when the lesion is in the pontile sensory nuclei (Brouwer), especially in the pontile nuclei plus the spinal root.

As irritating phenomena in diseases of the sensory area of the medulla oblongata there are paresthesias, burning sensations, etc.; extremely fine or deep stimuli are perceived as painful and are badly localized (Mann, Weisenburg-Mills).

All sensory tracts reach the thalamus. According to the general conception, lesions of the ventrolateral thalamus cause sensory disturbances. According to Wallenberg, lesions of the ventromedial area should lead to disturbances more of the posterior column type; lateral and ventrolateral lesions more of the type of the anterolateral tract. Concerning individual body areas, it is assumed that the thalamus is divided as in the posterior central region.

Wallenberg's opinion is that the centrum medianum of Luys is the focus for the head. Extremely light sensory irritations develop very severe pain and very unpleasant sensation, with an indefinite localization.

All sensory tracts passing through the thalamus reach the sensory cortical area. The gyrus postcentralis and the upper parietal portion are the perception areas for sensory stimuli. Many authors also include the lower parietal area. According to Förster, in addition to these areas, other parts of the cortex are sensitive to sensory stimuli, as was shown experimentally by Dusser de Barenne in lower animals.

The basis for the topical results in cortical sensory disturbances is that of the precentral gyrus, as both have a similar arrangement.

Cortical lesions develop types similar to that of the thalamus: (1) Hemianesthesia or hemihypesthesia (especially in subcortical lesion) is often present though there is not always a midline demarcation. (2) The type affecting a particular part, as of the arm or leg, the finger, the head, with or without involvement of the same side of the trunk. (3) The segmental type, embracing an area of sensory disturbance corresponding to a skin segment. This type is often associated with homolateral sensory disturbances of the trunk (Redlich), with diseases of the ulnar area (fourth and fifth fingers) or the peroneal type, embracing the foot and fourth and fifth toes. There are also mixed forms of ulnar and radial or ulnar and peroneal type as well as other combinations. (4) The circulatory type, mostly affecting the extremities, the glove and stocking type.

No general rule can be given as regards the arrangement of the individual sensory qualities in the areas mentioned. A complete hemianesthesia for all qualities may be present, especially in cortical plus subcortical lesions; the posterior tract qualities (especially sense of space) may alone be affected, or other qualities may be involved; more rarely temperature disturbance alone is found, or touch and temperature disturbances combined. Any dissociation may take place. As a rule, the most common sensory disturbance found in cortical lesions is that of posterior tract qualities, especially a disturbance of sense of space and cutaneous localization.

Restitution in cortical sensory disturbance takes place in the trunk and face from medial to lateral (Redlich), in the extremities in a proximal-distal direction (Goldstein and Pfeiffer).

Nothing definite is known concerning the cortical representations of the sensory qualities. Economo and Koskinas, also Monakow and Kleist, suggested that pure tactile sense is more in the anterior wall of the postcentral; the deep qualities more in the posterior wall, perhaps also in the gyrus supramarginalis. As irritation phenomena, there are especially the sensory jacksonian attacks, with paresthesia, burning, formication, etc., which occur in the part of the body corresponding to postcentral topical arrangement in the longitudinal direction. Permanent sensory disturbances are seldom observed in these cases.

The frequent sparing of the genito-anal region is not characteristic of a cortical disturbance. Lesions of the medulla, pons and thalamus, not seldom spare the area of the mouth and eyes. This sacral exemption is found in diffused and not in complete lesions, whether funicular, pontile, thalamic or cortical. Within the anogenical region there appear various dissociations of the individual sensory qualities (Förster, Pfeiffer, Carplus) as well as sparing of large areas in the region of the anus, scrotum and perineum. The special vulnerability of posterior tract quality is also not especially characteristic for cortical sensory disturbance. In diffuse lesions of peripheral nerve stems, as well as at restitution after a peripheral nerve lesion, there may be observed a special vulnerability for cutaneous sense of space. In funicular disturbances this may also be observed. The greater vulnerability of the posterior tract quality is explained by Brouwer on the basis that the posterior tracts and their portion of the lemniscus medialis are phylogenetically the youngest of the sensory nervous system; they follow the general law of greater vulnerability of phylogenetically younger conductive tracts. Added to this is Dusser de Barrennes' clinical and experimental observation that sensation of touch, and especially that of pain and temperature, particularly of the extremities, of cortical type appear to be double-sided, while cortical posterior tract types are contralateral. Different explanations are offered for the frequent observations of distal disturbances in cortical lesions. Anatomic relations are given by Goldstein, disturbance of functional mechanism by Marburg, and phylogenetic relations by Förster.

Schwab calls attention to the tegemental development which results in the midline of the body forming the nucleus for a bilateral symmetrical development. In the most primitive stage of the tube, the extremities begin gradually to push away from the midline. These distal parts (hands and feet) differentiate progressively as regards form and function. If one assumes that the younger and more highly differentiated parts are more vulnerable, one can understand why the distal parts of the extremities are especially badly affected in diffuse lesions of different sensory tracts and centers, while the trunk and midline regions are less affected. It will also explain the sparing of the mouth, eyes and anogenital region, areas which lie in the midline or near to it.

DISCUSSION

Dr. Spiegel: I call attention to my experimental observation, with Wassermann, that stretching the wall of the aorta as well as stimulation of the adventitia will cause pain. This aortic pain comes via the stellate ganglion. Cutting the vagus and cervical sympathetic does not prevent its onset. The further course of this pain (from experiments in association with Singer) is over the posterior roots from the eighth cervical to the fourth dorsal.

Dr. Pötzl: I observed, in a patient with an abscess in the right frontal area, peculiar attacks which began with a crawling sensation in the right hand and forearm, jumped over the left arm, and then to the right leg. The attacks were followed by tonic contractions. The patient showed occasional disturbance of gait. I consider this clinically analogous to the phenomenon of Dusser de Barennes. Together with Max Löwy I also observed, in a case of endothelioma of the right parietal lobe, which reached below the postcentral convolution, peculiar attacks of paresthesia which clinically can be considered as double-sided jacksonian sensory attacks. They remained for a long time, even after a successful operation. Each attack lasted from one to two minutes and showed itself as a crawling sensation in the left hand and in the right corner of the mouth, at times affecting both places together and at times one following the other.

Dr. Pette: In sympathotectomy and its relation to pain, I found, though not always, that such patients will develop other types of pain after the operation. Two patients on whom extirpation of the cervical ganglion was done on account of asthmatic complaints developed trigeminal neuralgia; recently, three other similar cases have come to my attention. The attacks of pain were so characteristic that they could not be differentiated from true trigeminal neuralgia. In these

patients both the upper and the middle cervical ganglion was removed. After extirpation of the lower cervical ganglion other symptoms were observed. The patients complained of peculiar sensations of heaviness and pulling downward in the shoulder and arm of the same side. At the same time objective sensory disturbances were found. Stimuli of all kinds were differently and not fully perceived. From these observations I concluded: (1) that the sensation of pain has an intimate relation with the function of the vegetative sphere; (2) that each individual sensory quality is subject to the influence of the sympathetic system, the degree of the disturbance depending on individual variations and constitutional moments. Cervical sympathotectomy permits the observation that the disturbed sensory area is dependent on the seat of the lesion. When the upper cervical ganglion is damaged, the involvement embraces the hairy part of the head; extirpation of the middle cervical ganglion involves the face, and after extirpation of the lower cervical ganglion the arm, the chest and back are involved. The fact that, aside from the ganglion chain, there are also ganglion cells in the peripheral fiber net, leads to the conclusion that its function must be different from that of the cerebrospinal system. The ganglion cell content in the peripheral system permits the local area a certain independence in elaborating the local stimuli. Such an explanation makes understandable the appearance of local, limited, sensory and vasomotor disturbances, especially as observed in predisposed individuals, or after trauma with local edema and pain.

Dr. Rieder: After experimenting on eighty dogs, twelve acute and sixty-eight chronic, I could not substantiate that superficial or deep sensibility pass through the anterior root. In the chronic experimental animals some of the dogs were kept alive three fourths of a year after posterior root section was done.

Dr. Economo: In a discussion of sensation, it is important to consider the brain cortex where the stimuli attain apperception. It is known that the human brain has about six cell layers. Also, according to the composition of these layers, the brain cortex can be divided architectonically into different and at times independent areas, with apparently each one having an individual function. I have shown that although there are many individual architectonic fields (over 100) they can be grouped into types of which I have classified five. In type 5 the cells are smaller so that the largest number are of a nuclear size; at the same time there is an increase in the number of cells and a narrowing of the cortex; the fifth layer is lighter, the sixth layer is composed largely, not of spindle cells but of small triangular cells. The fifth layer on account of the smaller size and greatly increased number of cells appears dusty-like; therefore I named it Koniocortex (Dust-cortex). The koniocortex is found in the brain cortex in five places; in the walls and lips of the calcarine fissure, in the forewall of the posterior central convolution, in the Heschl convolution (in the Sylvian depression), in the retrosplenial area, and in the inner wall of the gyrus hippocampi. But these are the five places in which have been localized the pathophysiology of the five senses, and it is more than probable that in the koniocortex there is the anatomic expression of the sensory function of the cortical areas: the visual sphere, the touch sphere, the hearing sphere, the olfactory sphere and the taste sphere. Further, this cortex measures on an average 2.5 mm. more thickness; in its thickest part it measures 4.5 more, in the touch and visual area the cortical thickness is below 1.5 mm.; the average cell count in 1.0 sq. mm. of cortex is 61,000; in the visual area it is 217,000; the size of the pyramidal cells in the third layer is 25 by 12 microns, while in the visual field it is 8 by 6 microns. The fifth layer in these areas is composed of a thick myelinated fiber net, which is formed by the conducting specific sensory stimuli. In the visual field of the area striata, this fiber net, or its largest part, is not found in the fifth but in the fourth layer, where it forms the so-called Gennari lines which are formed by offshoots from the optic radiation. Common to all the koniocortex is the nuclear cell type, the narrowing of the cortex and the conducting fiber net. Yet each koniocortex shows its special structure. The superficial extension of each of the sensory areas shows differences. While the area of the visual field takes

in about 25 sq. cm. in each hemisphere, the koniocortex of touch takes about 18 sq. cm., the hearing sphere only 3.5 sq. cm., the taste sphere scarcely 2 sq. cm., and smell even less. The koniocortex is also subject to individual variations; for instance in different subjects the expansion of the area striata may fluctuate from 20 to 44 sq. cc. It is possible this may have some relation to the fineness of sense perception. Particular parts of the koniocortex correspond to particular sense organs. The question is now, does the cortex neighboring on the koniocortex, which does not possess these types of cells, also function in the capacity of receiving sensory stimuli? I am unable at present to answer this question, but am inclined to answer it in the negative; at the same time I do not exclude the possibility that there may be transitory areas capable of receiving sensory stimuli, although perhaps imperfectly. The development of the individual koniocortices varies with the different lower animals. So far, it has not been possible to find in lower animals an anatomic equivalent for the koniocortex of the hearing area, although it can hardly be assumed that the sound stimuli do not receive apperception in the cortex; most likely in these animals the degree of the cortical sensory differentiation is rather light and therefore it cannot be distinguished so readily from the ordinary sixth layer.

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WALTER M. KRAUS, M.D., *Chairman of the Section in the Chair*

SYMPOSIUM ON DISORDERS OF THE SKIN, HEART AND ALIMENTARY CANAL, DEPENDENT ON DISORDERS OF THE CENTRAL NERVOUS SYSTEM

SOME CENTRAL CONNECTIONS OF THE VEGETATIVE NERVOUS SYSTEM. DR. SMITH ELY JELLIFFE.

Dr. Jelliffe first spoke of the importance to internal medicine of a knowledge of the structures of the diencephalon, in which are to be found the chief coordinating centers for the vital functions of the human body underlying the vis medicatrix naturae, as well as the main regulators of metabolism.

He demonstrated by lantern slides a restricted portion of this important field, showing the main vegetative nuclei and their connections with the rest of the nervous system. He spoke of humoral hypotheses as "autistic thinking." They explain nothing. Only a knowledge of the neural mechanics can show how the body as a transformer and deliverer of energy works. Most important links in this chain are found in the diencephalon of the human being. Bodily health, the sensation of well-being, and definite metabolic functions, such as thermal regulation, electrolyte balance and tissue tension are chiefly controlled at this level of the nervous system. These controls are mostly automatic and beyond conscious control, that is, they belong to the primitive unconscious processes. There are, however, definite cortical connections in higher animals. These predicate the fact that the automatic processes may be disturbed through higher cortical, that is, symbolic representations. In this manner it can be seen how "fear" operates to disturb the "well-being" of the body and can interfere with the "vis medicatrix naturae." Dr. Jelliffe confined himself to the anatomic substratum of complicated psychic processes.

NEUROGENIC AND PSYCHOGENIC DISORDERS OF THE SKIN. DR. JOSEPH JORDAN ELLER.

The modern dermatologist does not look on the skin as an organ sui generis, diseases of which have no influence on other parts of the body, or vice versa. The

skin and nervous system are closely related. In fact, it is through the medium of the nervous system that the skin performs its varied physiologic activities. The skin forms the protective covering of the body. Distributed over its surface are nerve fibers of pain, temperature and touch, and the body adapts itself to changes in its environment by means of these fiber reflexes.

In the past physiologists have taught that the regulation of the body temperature by the skin is affected by blood supply and sweat secretion. There is a newer point of view regarding the functions of the skin. In an editorial on the sweat glands in the *Journal of the American Medical Association*, Feb. 14, 1925, the statement was made that "the skin plays a significant part in temperature control through its ability to conduct heat and evaporate water." All of the functions of the skin mentioned are under nervous control.

In a large number of patients suffering from diseases of the skin one finds pathologic changes in other organs; for example, certain disorders of the skin have a definite relation to organic disturbances of the central or peripheral nervous system. On the other hand, patients with diseases of the skin show psychic changes, which vary from slight nervous disturbances to pronounced psychoses.

The epidermis and the central nervous system develop from the ectoderm. Damage to the latter or alterations in its embryonal development might produce changes from the normal in the skin, as well as in the central and peripheral nervous system. The skin may be looked on as an organ of sense, which is in continuous contact with the brain by way of the nervous system. It can thus be seen that certain disturbances of the nervous system, either organic or functional, might produce alterations from the normal in the skin.

In functional disturbances of the nervous system, such as in hysteria and neurasthenia, patients seem easily able to simulate or to suggest to themselves diseases of the various organs, among which diseases of the skin are included; the latter is a favorite location for the complaints of neurasthenic patients. Skin symptoms may occur simultaneously in a neurotic person as the result of the neurosis which causes alterations in the functions of the gastro-intestinal tract. The sympathetic nervous system is the seat of important functions for the mind as well as for the skin. The internal secretions, the influence of which may be conveyed by the sympathetic nerves, may produce mental changes as well as changes of the skin, and it is in this way that dermal and psychic diseases often occur jointly as symptoms of the same cause.

It seems at times that there is a connection between psychic alterations and certain trophic and pigmentary disturbances of the skin. This might be explained by the fact that the emotions may exert an influence on the organs of internal secretion and following the endocrine disorders various pigmentary and trophic disturbances of the skin may result.

The study of internal secretions and their influence on the psyche and the whole organism have suggested immense explanatory possibilities for a large number of pathologic changes, particularly in the skin. Many vasomotor disturbances appear only as an expression of irritation of blood-vessel innervation by hormonal influences. In pronounced emotional states, for instance, an enlargement of the thyroid gland, hypophysis and increased secretion of epinephrine may occur (Pel, Katsch, and others cited by Gadelius). Strandberg (Psychogenese und Psychotherapie körperlicher Symptome, Berlin, Julius Springer, 1925) says that a congenital disorder of the autonomic nervous system may cause various diseases of the skin produced by trophoneuroses and angioneuroses. Coincidently with vasomotor alterations one finds abnormal sweat secretion. In syringomyelia, hysteria, exophthalmic goiter and other conditions there is often increased perspiration.

It is beyond doubt that the hair may turn gray prematurely by worry and trouble, and there have been reports that hair has turned white over night following sudden shock. This has been doubted by various observers, among whom are Hebra and Kaposi. Strandberg cites a case of Reinhard, a patient suffering from manic-depressive insanity who had alterations in the color of her hair occurring rather regularly. During the stuporous period the color of the hair was light

yellow, while during the state of excitation, the hair became darker, with a golden red tone. The changes in the color which occurred on the tips of the hairs appeared during the first day of the patient's mental change.

Total loss of hair following traumatism of the central nervous system as well as following psychic shock has been reported in the literature. Strandberg says that psychic factors undoubtedly play a part in certain cases of alopecia areata. He refers to the work of Rock, Poehlmann and Strandberg. O'Donovan (Dermatologic Neuroses, London, Trubner & Co., 1927) also attributes a psychic condition as one of the main etiologic factors of alopecia areata. Strandberg quotes a case of total alopecia in a patient with dementia praecox. With the occasional remissions of the mental disease the hair began to grow again.

Changes in the nails may occur from psychic as well as from nervous disorders. Oppenheim (Textbook of Nervous Diseases, New York, Otto Schulze & Co., 1911), Strandberg, Heller and others mention this, and Heller (Die Krankheiten der Nagel, Berlin, Julius Springer, 1927) has devoted many pages in his monograph on diseases of the nails to the various disturbances of the nails due to certain diseases of the nervous system. Heller says that various trophic disturbances of the nails occur, particularly in insane persons. He mentions that Papillon found disturbances of the nails in 250 of 1,050 insane patients examined. Heller observed that changes in the nails are also frequently found in delirious, epileptic and paralytic patients.

The accompanying table founded on the observations of Heller, Cassirer, Oppenheim and others, shows the great variety of lesions of nails that may result from injury to the peripheral nervous system.

General Symptoms Occasionally Observed in the Nails After Injury of Peripheral Nerves

Early Stage of Nerve Lesion

1. Hypertrophic symptoms (increased growth of nail)
2. Atrophic symptoms
   (*a*) Decreased growth of nail
   (*b*) Thinning
   (*c*) Falling out of nails
   (*d*) Loss of luster
3. Deformities, such as:
   (*a*) Striation
   (*b*) Bending
   (*c*) Ridging (longitudinal; transverse)
   (*d*) Beading (pearl formation)

Later Stage of Nerve Lesion

1. Atrophy of nails
2. Arrest of growth of nail
3. Decrease in size
4. General deformity
5. Falling out of nail
6. Loosening of nail
7. Ulceration of the walls of the nail
8. Bleeding underneath nail
9. Ridging (longitudinal; transverse)
10. Hardening
11. Onychogryphosis
12. Fusion of nail (nailbed sign—Alfoldi)
13. Longitudinal and lateral curving of nail

Among the pigmentary changes that occur in the skin directly or indirectly from psychogenic or neurogenic disturbances may be mentioned vitiligo (or loss of pigment in patches), cloasma (increased pigment in patches), von Recklinghausen's disease, and the changes in pigmentation of areas of the skin affected with scleroderma and other diseases of the skin resulting from trophoneuroses.

Vasomotor and trophic symptoms of the skin may be found in many insane persons. Acrocyanosis, abnormal hair growth, anomalies of the sweat and sebum secretion have been described by some observers.

The joint occurrence of congenital malformations in the skin (nevoid diseases) and psychic inferiority has frequently been reported. Among some of these conditions may be mentioned von Recklinghausen's disease, adenoma sebaceum, marked ichthyosis, epidermolysis bullosa hereditaria, alopecia congenita, congenital changes in the nail and extensive pigment anomalies (Strandberg, also Bettmann, quoted by Strandberg).

These combined malformations and psychic abnormalities of the skin are possibly due to injuries of the ectoderm which occurred during fetal life. Consanguinity and degenerations caused by alcoholic abuse and syphilis may play a rôle in some cases.

Various factors influence the tonus of the blood vessel, such as the psyche and the vegetative nervous system. These may both be influenced by the internal secretions. When a psychic disturbance affects the tonus of the blood vessels, it does so by way of the vegetative nervous system.

It is difficult to classify disorders of the skin resulting from disturbances of any part of the whole nervous system. Dermatoses which manifest themselves as vasomotor and trophic disturbances do not, as a rule, represent a clinical entity. They are usually secondary to various organic and functional nervous disorders. The organic lesions of the central and peripheral nervous system are manifold and may produce various conditions of the skin. In syringomyelia there occur trophic disturbances of the finger-nails and skin of the hands; in tabes dorsalis, perforating ulcers of the feet; in leprosy, trophic disturbances of the skin of the hands as a result of the involvement of the ulnar nerve; various trophoneuroses and angioneuroses of the skin result from traumatism to the brain or spinal cord.

When organic lesions of the nervous system produce manifestations of the skin, they do this through the interaction of the central and peripheral nervous system and the vegetative nervous system.

Diseases of the skin of nervous origin are often regarded under two main headings, psychogenic and neurogenic. As can be seen from the foregoing, this may easily lead to confusion, for such sharp distinction cannot be made. Many disorders of the skin may be of both psychogenic and neurogenic origin. Again, disturbances of psychic origin, in exerting their influence on the skin, do so through nerve pathways; examples of this are pallor from fright, blushing, horripilation (erection of the hairs of the skin), cutis anserina (goose-flesh), and changes in the sweat secretion. For these reasons and as a practical working basis I have put the neurogenic and psychogenic disorders of the skin into five main groups, as follows:

Group 1: Disorders of the Skin Due Exclusively to Psychic Disturbances

1. Dermatitis factitia Mythomania of Dupré (deception always practiced)	Various degrees of dermatitis from a simple erythema to the so-called "neurotic" gangrene.
2. Neurotic excoriation Dermatothlasia (no deception intended)	Compulsion neuroses

3. Trichotillomania
4. Trichokryptomania
5. Dermatophobias
   - (*a*) Syphilophobia
   - (*d*) Parasitophobia
   - (*c*) Cancerophobia ("burning tongue," etc.)
   - (*d*) Bromidrosiphobia
   - (*e*) Rupophobia
   - (*f*) Peladophobia

Group 2: Disorders of the Skin Frequently Due to Psychic Disturbances (Although Not Exclusively)

1. Urticaria
2. Angioneurotic edema (also in group 5)
3. Erythema (may later lead to rosacea)
4. Pallor (sudden)
5. Horripilation
6. Cutis anserina (goose-flesh)
7. Pruritus (cutaneous; anal; vulval)
8. Tattoo marks (disputed)
9. Changes in sweat secretion (hyperhidrosis; hypohidrosis)
10. Paresthesias (hyperesthesia; anesthesia)
11. Pemphigus hystericus
12. Alopecia areata (also in group 5)
13. Lichen planus
14. Certain eczemas, such as those due to allergy (also in group 5)
15. Dermatitis herpetiformis
16. Psoriasis
17. Dermatitis dysmenorrheica (also in group 3)
    Note: Items 11, 12, 13, 14, 15, 16 and 17 are disputed by most observers

Group 3: Disorders of the Skin Frequently Associated with Psychic Disturbances Although Not Necessarily Due to Them

1. Congenital malformations (nevoid diseases)
   (*a*) Von Recklinghausen's disease (also in group 4)
   (*b*) Adenoma sebaceum (Pringle)
   (*c*) Marked ichthyosis
   (*d*) Alopecia congenita
   (*e*) Cutis verticis gyrata (microcephalic idiots)
   (*f*) Epidermolysis bullosa hereditaria
   (*g*) Albinismus
   (*h*) Congenital pigmentation anomalies
2. Trophic disturbances of the hair and nails (also groups 4 and 5)
3. Anomalies of the pigment (particularly vitiligo) (also groups 4 and 5)
4. Pellagra (also in group 4)
5. Pellagra in alcoholic patients (pseudopellagra)
6. Beriberi
7. Scurvy
8. Erythredema polyneuritis (acrodynia) (Butler, also Foerster)
9. Erythromelalgia (also in group 5)
10. Herpes simplex (disputed) (also in group 4)
11. Dermatitis dysmenorrheica (disputed) (also in group 2)

Group 4: Disorders of the Skin Due to or Associated with Organic Disturbances of the Central or Peripheral Nervous System

1. Herpes zoster
2. Syphilis (perforating ulcer of tabes dorsalis)
3. Trophic disturbances due to syringomelia
4. Trophic disturbances due to myelitis (infections, etc.)
5. Trophic disturbances due to multiple sclerosis
6. Trophic disturbances due to tumors of the central or peripheral nervous system
7. Trophic disturbances due to traumatism of the central or peripheral nervous system
8. Trophic disturbances due to epidemic encephalitis
9. Trophic ulcers due to arteriosclerosis of blood vessels of spinal cord
10. Leprosy (also in group 5)
11. Von Recklinghausen's disease (also in group 3)
12. Pemphigus (disputed)
13. Pellagra (disputed) (also in group 3)
14. Herpes simplex (disputed) (also in group 3)
    Note: When skin breaks down (trophic disorder) in the presence of a mental disease, it is evident that the mental disease is due to an organic disturbance.

Group 5: Disorders of the Skin Often Attributed to Disturbances of the Vegetative Nervous System (Angioneuroses and Trophoneuroses)

1. Angioneurotic edema (also in group 2)
2. Scleroderma
3. Raynaud's disease
4. Erythromelalgia (also in group 3)
5. Progressive facial hemiatrophy
6. Certain eczemas, particularly of the allergic type (also in group 2)
7. Alopecia areata (also in group 2)
8. Trophic disorders of the skin found in
   (*a*) Syringomyelia
   (*b*) Multiple sclerosis
   (*c*) Myelitis (complete and incomplete)
   (*d*) Tumors of the central or peripheral nervous system
   (*e*) Traumatism of central or peripheral nervous system
   (*f*) Epidemic encephalitis
   (g) Arteriosclerosis of the blood vessels of the spinal cord
   (*h*) Leprosy (also in group 4)

While there is concurrence of opinion in regard to the interrelation of the psychic conditions and disturbances of the skin generally, many divergent views are held by observers concerning various specific disorders.

The etiologic factor in a number of diseases of the skin is still unrecognized. Their occurrence coincident with psychogenic disorders, however, is frequently noted. Although it is impossible to show by any palpable means a direct connection between neurogenic, psychogenic and dermatologic conditions, it is likely that a study of their joint occurrence, with a view to their possible causal relation, may help in solving many perplexing problems.

It seems evident that a better understanding of the interrelation or interdependence of psychic disorders and of disturbances of the skin is necessary; it is apparent also that there is urgent need of improved methods in the study of the innervation of the sympatheticus and its pathology, as well as its relation to the internal secretions. It is vastly important that the dermatologist recognize the psychogenic origin in dermatoses, for many of these conditions hardly come within the realm of dermatology. Such a patient should be treated in collaboration with a neurologist.

Psychogenic Heart Disease. Dr. John Wyckoff.

Cardiac psychoneuroses may be classified as: (1) fatigue neurosis (neurasthenia); 2 introspective neurosis (hypochondria); (3) anxiety neurosis; (4) substitution neurosis (hysteria), and (5) obsession neurosis (psychasthenia). Of these, the fatigue and introspective neuroses are extremely common. Substitution neurosis is less common, and anxiety and obsession neurosis rarely cause symptoms of heart disease.

Fatigue neuroses which were extremely common in the World War are also seen in civil life. These patients exhibit two characteristics: (1) A history of marked nervous instability, either in the patient's family or in the past history of the patient himself, such as nervous prostration or neuroses referred to other organs than the heart. It is common to secure histories of one or more abdominal or gynecologic operations performed for the relief of subjective symptoms or symptoms of long standing. (2) There is a history of an exciting cause in the patient's environment. This may be physical or mental effort, business and financial worries, family infelicities or seemingly trivial difficulties.

The unstable nervous system and the exciting causes are both present always, but in an inverse relationship; the more stable the nervous system the greater will have to be the exciting cause to bring about symptoms, and the more unstable the nervous system the less need of an exceptional environmental trauma to produce them. In civil life, usually only the more unstable develop this type of

neurosis, though at times of marked business depression, after disasters or after great sorrow, symptoms appear among persons who seem normal.

The symptoms are fatigue, palpitation, precordial pain and a sensation of breathlessness. Usually these symptoms are increased by effort, and not unusually the patients have attacks of dizziness and syncope. On examination they appear worried and nervous, and talk a great deal of their symptoms though not as much as do the introspective neurotic persons, their hands tremble, and frequently their skin shows signs of vasomotor instability. The heart is rarely enlarged, the rate being usually 100 or more, sinus arrhythmia is the rule, but ventricular premature contractions and paroxysmal tachycardia are not uncommon. A short systolic murmur may be present. Roentgenographic and electrocardiographic examinations usually give negative results.

Many of these symptoms come from a lowering of the threshold to normal physiologic processes. Often these patients have palpitation with regular hearts, not too rapid, and with normal blood pressure. Often they feel short of breath with normal respiratory rates. At other times they have tachycardia and rapid, but usually shallow, respiration.

Among the cardiac neuroses occurring in civil life, introspective neuroses form the largest group. These patients present some subjective or objective symptoms of heart disease, usually from an extracardiac cause, and dwell on the symptom or symptoms, worry about them, collect reports of various examinations made by different heart specialists, compare them, worry about the fact that the authorities differ, consult others and talk continuously to every one about their symptoms. In exaggerated cases of this sort, the patients own a stethescope, keep charts of ventricular and pulse rates and make long notes of trifling symptoms which they read to suffering physicians at great length.

The symptom that usually first attracts the attention of the patient is one of the common irregularities in rhythm — a marked sinus arrhythmia, premature contractions or an attack of paroxysmal tachycardia. The condition of at least some of these patients is due to improper interpretation of symptoms and signs by physicians. Even after the symptoms which may have excited this type of neurosis have disappeared for years, the patient will go on asserting and believing that he has heart disease.

Occasionally, as patients grow older, they actually develop arteriosclerotic heart disease, and then there is great danger of missing the early signs of organic disease because the patient is still believed to have a neurosis. Once at least I made such a mistake.

This type of neurosis sometimes develops in a patient with mild organic heart disease and makes a difficult complication. Such a patient without an objective sign of heart failure, with only slightly diminished or no diminution of cardiac reserve, but with signs of slight organic heart disease, may spend years as an invalid because of the development of a fixed idea of the gravity of his or her condition.

Patients with anxiety neurosis may have cardiac symptoms — the most usual symptom is palpitation. As White says: "These patients rarely present a problem to the internist, as the cardiac symptoms are so overshadowed by the state of tension, sleeplessness, illogical worries and inability to concentrate."

On the other hand, patients suffering from the substitution type of neuroses may develop attacks of pain in the heart which are difficult to differentiate from pain in severe organic disease of the heart. Attacks of so-called "pseudo-angina" occur as typical hysterical manifestations, and the differentiation may be difficult if the patient is first seen during the first or second attack, but usually is not difficult if the physician knows the patient and follows the course of the illness.

Obsession neuroses rarely manifest themselves by cardiac symptoms.

In the foregoing discussion, reference to etiology, other than fatigue, as a cause of these neuroses has been avoided. That there must be some reason for believing that a relationship exists between their cause and the endocrine secretions becomes evident when one notes the remarkable glandular therapy which the

patients have received. Usually such therapeutic procedures have been without control, and the results obtained, if viewed objectively and with due consideration of the laws of probability, are far from convincing. It has seemed to me that the best results therapeutically are obtained in the following way: Accept the patient's symptoms as facts, examine him with care and thoughtfulness. Explain to him that signs of structural disease are not present, though all methods of exploration have been used. Explain that normal physiologic function may creep over the threshold of consciousness and give rise to symptoms. Explain how this threshold is best kept high. Describe the likelihood of relapse and when such relapses are apt to occur. If possible get rest, mental and physical, for the cases of fatigue, and be sure that it is rest that the patient is getting and not some other thing which some member of the family or solicitous friend thinks may do him good. Secure suitable mental and physical occupation for the introspective group. Build up the general health of the patient, and keep it at as high a level as possible. Avoid placebos, but treat him honestly and as an intelligent being. When needed, give simple sedatives. Under such a common sense regimen many of the patients improve and live useful lives.

Neurogenic Disorders of the Heart. Dr. Ernst P. Boas.

The heart rate and rhythm depend on variations in the degree of excitation of the two sets of nerves. These variations are determined by reflexes passing over innumerable afferent pathways. This regulation of the activity of the heart is an adaptive mechanism enabling the heart to meet the demands placed on it by the varying activities of the body. Loss of this regulatory function may have serious consequences. Complete denervation of the heart, that is, severance of all of the extrinsic cardiac nerves, greatly restricts the activities of an animal. In dogs who have survived this operation for many months the circulation is adequate when they are at rest, but any greater physical exertion is impossible. The animals collapse from exhaustion, and there is no acceleration of the heart. The characteristic reactions to atropine and epinephrine are also lacking, and thyroid feeding does not bring about tachycardia.

The afferent arcs of the cardiac reflexes may arise in almost any part of the body. They may come from the heart itself, from the lungs and other viscera, they may pass through the segmental parts of the nervous system, namely, the cranial nerves or the spinal nerves. Afferent impulses may also reach the vagus and sympathetic nuclei from all suprasegmental parts of the brain. One need but recall the changes in heart rate accompanying emotions and varying psychic states. Convincing proof has not been offered of the existence of cardiac reflex arcs to the hypothalamus, and I believe with Francois-Franck and with Tigerstedt that the vital cardiac reflex arc passes through the medulla and that the brain acts as a peripheral organ initiating reflexes via the medulla.

The following classification of neurogenic disorders of the heart may be attempted. Its value lies chiefly in its demonstration of the limitations of our knowledge.

A. I. Disorders of Nervous Structures in the End Organs
- 1. Vagus
- 2. Sympathetic

II. Disorders of the Ganglionic Arc
- 1. Vagus
- 2. Sympathetic

III. Disorders of the Segmental Arc
- 1. Vagus
  - (*a*) Nerve trunk
  - (*b*) Dorsal nucleus
- 2. Sympathetic

IV. Disorders of the Hypothalamic Arc
- 1. Vagus
- 2. Sympathetic

B. Disorders Due to Excessive or Exaggerated Afferent Stimuli
   1. Segmental
      (a) Somatic
      (b) Visceral
   2. Suprasegmental
      Cerebral (abnormal mental states)

C. Disorders Due to Increased Irritability of Visceral Nervous System of Unknown Localization
   1. Constitutional
   2. Acquired
      (a) Infectious
      (b) Internal secretory

D. Disorders Secondary to Neurogenic Vasomotor Disorders

I do not know of any cardiac disturbances that may be placed in group one, two or four. Group three, disorders of the segmental arc, is represented in medical periodical literature by innumerable inconclusive case reports. There is hardly one which will stand critical analysis. Among the conditions which are supposed to lead to vagus tachycardia were compression of the vagus by mediastinal tumors, tuberculous lymph nodes, aortic aneurysms, alcoholic neuritis of the vagus and destruction of the dorsal vagus nucleus in bulbar palsy. Yet in practically every case there existed, in addition to the nerve lesion, other potent causes of tachycardia such as fever, dyspnea, toxemia or anxiety. On the other hand, neurogenous forms of Adams-Stokes syndrome have been described.

It is apparent that focal lesions of the extrinsic nervous apparatus of the heart do not play a significant rôle in the genesis of cardiac disorders. Neurogenic circulatory disturbances fall chiefly within the last three categories of the classification. The first group comprises cardiac disorders due to excessive or exaggerated afferent stimuli. Here may be grouped the simple tachycardias and occasional bradycardias associated with disease of the gallbladder, stomach and other internal organs. Of greater import, however, are the occasional cardiac irregularities that are initiated by reflex stimuli from diseased viscera.

Of equal importance are cardiac disorders due to increased irritability of the visceral nervous system. It is often impossible to determine to what extent the cardiac disorder is due simply to increased irritability of the extrinsic nervous apparatus of the heart, and to what degree it is secondary to neurogenic vasomotor disorders, or to an increase of afferent stimuli from the brain, for, as a rule, all three factors operate together.

As a result of the disturbed innervation of the blood vessels, the capillaries and venules in the splanchnic region and in other areas of the body are dilated and a large amount of blood becomes pooled in them. Consequently, there often is an inadequate amount of blood in the left ventricle and in the arterial tree. This lack makes itself felt particularly during and after exercise and undoubtedly contributes largely to the rapid pulse, the dyspnea and sense of exhaustion which follows physical exertion.

Neurogenic and Psychogenic Disorders of the Alimentary Canal. Dr. John L. Kantor.

From the point of view of the practicing gastro-enterologist, a survey of the current literature on neurogenic and psychogenic disorders of digestion yields the following impressions: 1. An increasing number of cases formerly diagnosed as "nervous dyspepsia" are shown on study by improved methods to be instances of actual organic disease of the digestive organs or of their nervous communications. 2. The autopsy observations of postinflammatory nerve lesions in cases of digestive disorders suggest the advisability of careful scrutiny of dyspeptic patients for evidence of past infections (such as tuberculosis) which might involve important nervous pathways in scars or adhesions. 3. The theory of autonomic inbalance occupies a prominent place in discussions of the etiology of such important digestive disorders as peptic ulcer, cardiospasm, intussusception and congenital pyloric stenosis. 4. In some digestive conditions (intestinal tuberculosis, some cases of

peritonitis), it is the secondary nerve changes and not the primary lesions which produce the "characteristic" symptomatology. 5. The concept of "solar syndromes," with or without actual lesions in the nerve plexuses, is advanced by some writers to explain the painful phenomena in a rather diverse group of abdominal conditions. 6. Lesions of the spinal cord may produce visceral effects either directly by involving the preganglionic fibers at their point of origin, or else indirectly by affecting the suprasegmental neurons connecting with these preganglionic fibers. The general result of destroying the superior connections is a release of the lower neuron reflexes. 7. Neural ileus is an important condition often leading to useless surgical exploration. This form of ileus may be due to lesions in either the segmental or suprasegmental arcs or to psychoses with marked depression. It is a common symptom of transverse myelitis. 8. Important centers regulating the functions of the entire involuntary nervous system are now known to be located in the diencephalon. Lesions in this region occur frequently in epidemic encephalitis, and occasionally in dementia paralytica and dementia praecox. 9. Psychic disorders of digestion are mediated through the emotions and through ideas causing conditioned reflexes. Conditioned reflexes therefore furnish a basis for the development of digestive habits, peculiarities and perversions. 10. The psychoneuroses are not uncommonly encountered by gastro-enterologists because the digestive symptoms are so prominent and varied. In melancholia, constipation is a particularly constant and stubborn manifestation.

DISCUSSION

Dr. George M. MacKee: Dr. Eller has added an exceedingly comprehensive article to this interesting and instructive symposium, but he was able to present only an abstract in the time at his disposal. The dermatoses have not been thoroughly investigated from a neurologic or any other standpoint. Consequently the etiology of most of the diseases of the skin is unknown. For this and other reasons, dermatology offers a lucrative field for creative scientific research. Thus far the results of clinical observation have led the dermatologic research workers into the fields of chemistry, biology, morphology, bacteriology and physics, rather than into the field of neurology, although many dermatologists have given serious thought to the neurologic angle. Certainly this phase of dermatology deserves more attention than it has received.

Dr. Eller has demonstrated that the dermatologist is aware of the neurogenic and psychogenic aspects of our specialty, and he has enumerated the diseases in which such factors are thought to be of etiologic, symptomatic and therapeutic importance. He has been specific.

Every teacher of dermatology has noted the effect of suggestion while demonstrating a case of severe pediculosis corporis and discussing the subject before a large body of undergraduate medical students. The nude patient, who is covered with scratch marks, is scratching with both hands and one foot. The live insect is shown on the underclothes. Soon the students become restless and some of them begin to itch and scratch. Vigorous scratching or rubbing, especially when persistent, is one of the many causes of dermatitis. Such insult to the skin may effect excoriations, infections or eczema. There is a dermatosis called neurodermatitis that is thought by some to be neurogenic in nature, which often begins with pruritus, the subsequent symptoms such as dermatitis and lichenification being due to persistent rubbing in patients who have a predisposition to lichenification. It is important, when possible, to determine in all types of pruritus whether the itching is metabolic, toxic, psychogenic, neurogenic, or due to local pathologic changes or to contact with chemicals, plants, insects or other irritants.

There is an interesting congenital disease known as monilethrix in which the hairs are regularly beaded. The large portions (beads) represent normal hair, while the narrow interspaces are abnormal. In other words, the hair grows normally for a few weeks, abnormally for a few weeks, and so on with surprising regularity. Surely there must be a neurologic factor in this, but whether the basic trouble is in the nervous system, the endocrine system or the appendages of the skin is not for a clinical dermatologist to say.

While an abnormal nervous system may be the cause or partial cause of some dermatologic conditions such as eczema, pruritus, herpes, alopecia dermatitis and artefacta, one must realize that some diseases of the skin cause neurologic symptoms. Such a disease is acne vulgaris. This condition is common during adolescence and is disfiguring and humiliating. Some such patients become introspective and reclusive, and evidence of permanent psychic trauma may be detected years later by changed disposition and temperament. Because of the disease alone, or because of complications, occasionally patients with acne become psychopathic. Many diseases of the skin influence the conscious or subconscious mind to such a degree that the dermatologist is obliged to resort to various types of psychologic treatment in order to effect a cure. Too much importance, however, should not be placed on the neurologic factor in diseases of the skin, either etiologically or therapeutically.

In conclusion, permit me to devote a moment to dermatitis artefacta, especially to the differentiation between malingering and neurotic excoriations. The dermatologic conception of malingering is that the patient intentionally produces a dermal artefact by some mechanical or chemical means with the definite purpose of deceit, to create sympathy or perplexity in the minds of others, to escape work or punishment, to collect insurance and for other reasons. It is almost impossible to obtain an admission of guilt.

Neurotic excoriations are produced also by the patient, but for entirely different reasons. There is no attempt to deceive. The patient will instantly admit self-mutilation and will give the reasons. A simple example is the elderly, bald headed man, who more or less unconsciously picks at every little elevation on the scalp while reading — a habit. A trifle more complex is the person who cannot refrain from picking at some definite lesion such as a scar, a milium, etc. At the other extreme are patients who cause severe ulcers by working at some trivial lesion with instruments for several hours daily, or who scrub their bodies with strong soap until a dermatitis is produced. Such patients are obsessed with the idea that insects are causing the lesions and the subjective sensations (acarophobia — compulsory psychosis). It is often necessary to obtain neurologic help for this condition, in fact for all the conditions falling under the general heading of dermatitis artefacta, before the patient can be cured.

Finally, is it possible for a malingerer to produce a lesion of the skin by conscious or subconscious effort without mechanical or chemical aid? I think not. The eye of the dermatologist is well trained. He will detect characteristics of an eruption which escape the observation of others and which mean a great deal. It is possible, therefore, for him not only to identify an eruption or a lesion as dermatitis artefacta but to indicate how the lesion was produced. If it is suggested to such a patient that a lesion will appear in a given location at a given time, the lesion is likely to appear exactly as suggested, but it will not develop if the area is covered with a nonirritating bandage which will absolutely prevent the patient from applying anything to the skin.

Dr. Bernard S. Oppenheimer: I have been asked to discuss particularly the subject which Dr. Wyckoff presented, namely, cardiac disorders of psychogenetic origin, probably because I have been intensely interested in this subject since about 1917 when I had an opportunity to work under Lewis in a hospital in Colchester which had some 700 beds devoted to soldiers with cardiovascular disorders who were invalided from the British Expeditionary Force in France. A large majority of the men were suffering from symptoms which were not due to organic heart disease, but which were identical with the syndrome called "the irritable heart of soldiers" by Dr. Costa during our own Civil War, and also termed "neuro-circulatory asthenia" and "effort syndrome." In the nomenclature of the British army it was called disordered action of the heart, with the cryptic initials "D.A.H." I think an invalided but witty soldier hit the nail on the head; when asked what D.A.H. stood for, he replied, "That stands for a desperate affection for home." That is really what these soldiers were suffering from—simply an anxiety neurosis. We were not satisfied at that time

with the diagnosis anxiety neurosis and with discharging these men from the army, as their services were needed too badly at that time; the purpose of the investigation was to determine whether we could not get rid of the condition and return the men to full or partial duty. Without knowing any of the technic of psychoanalysis, we really did help a great many of them by a simple psychotherapy, occupation and especially by graduated physical exercise.

In going over 100 cases of them carefully with Dr. Rothschild, we found that 56 per cent had definite psychoneurotic factors in the family history; such factors included epilepsy, insanity and marked alcoholism. In a control group invalided from the same Expeditionary Force for wounds, only 38 per cent presented psychoneurotic factors in the family history. Evidently there is a psychoneurotic factor in the family history of these patients. In the personal history also 50 per cent proved to be of the constitutionally inferior or asthenic type. They were predisposed from birth to an irritable weakness of the whole nervous system, including the innervation of the circulatory system, and this accounted for the varying neuropsychosomatic symptoms. I believe that a fair proportion of those suffering from the same disorder in civil life have a positive family history and personal history of neuropsychic factors. In patients I have seen since then in civil life, it has not been so often a conflict which implicated the instinct of self-preservation, but a conflict in the religious and sexual spheres, and a great many are due to improper methods of contraception. Many other miscellaneous causes may result in an anxiety neurosis. In every case one ought not to be satisfied with the label "anxiety neurosis," but should try to discover the origin of the conflict. Many times one can do that oneself, but only an expert psychotherapeutist in the more complicated and obscure cases can get at the bottom of the disorder.

In 1917, I saw another group which in my opinion does not belong properly under what Dr. Wyckoff was discussing. Those were cases of hypertension which were evidently also psychogenetic in origin. The first was a man who could not get into the army — a valuable man. Every time he came up for army examination, his blood pressure was found too high; at other times his tension was normal. By reassuring him at the time of the test he finally passed. Recently, he died, and examination of his heart did not show any hypertrophy of the left ventricle, which is fairly clear evidence that he had never had prolonged hypertension. One of the best illustrations of hypertension resulting from emotional disturbance is the one described by Otfried Müller. He had a patient in the hospital for two months with a blood pressure of about 280 and attacks of pulmonary edema. The patient had diminished excretion of urine and slight albuminuria. After an interval during which he did not show any improvement, the man, who was softhearted, confessed that he felt guilty because he had been unfaithful to his wife. Müller suggested that he have his wife come, and under the protection of the hospital he made his confession to her. His blood pressure then dropped to 150, the attacks of pulmonary edema stopped and the albuminuria disappeared without treatment. Müller, after a few years, saw him again. His blood pressure was then 130. He had no symptoms; only a slight cardiac hypertrophy persisted.

Dr. Walter S. Bastedo: Some time ago Dr. MacLester reported that about one third of the patients who came to him with the complaint of digestive disturbances could be placed definitely in the psychoneurotic class. I think that is a fair average of the 2,000 coming to consult him. I do not mean by that that the patients are so profoundly psychoneurotic as to be cases for the neuropsychiatrist, because if they were they would not come to internists. They come to internists because they feel something the matter with them inside, whether it is the heart or the gastro-intestinal tract or what, and it is our duty to assess properly the underlying factor in the patient's condition.

I saw a girl with a good story of ulcer, who was sent to the hospital to be examined; she was given barium for roentgenographic study, and none of the barium passed from the stomach at the end of eighteen hours. In the morning she received a letter from her lover with whom she had a quarrel begging that the quarrel be made up; two hours later the stomach was empty. It was not an ulcer after all.

Another case was that of a man from Wall Street. He was neurotic and went to his physician who said, "Well, you are of that type that needs many vacations — more vacations than the normal man. Go and take a vacation." He did and came back feeling first rate. Six months later he had the same trouble with his stomach — empty pains, distress, symptoms resembling those of an ulcer for which he was taking sodium bicarbonate. For three years he continued to take vacations and a great deal of sodium bicarbonate. Then while he was away on one of these vacations he had two hemorrhages from the stomach and came home. There had never been a test of the function of the stomach, nor an examination of the stool. He had an ulcer.

That is the point I want to make, because I am only a therapeutist. What is one to do when a patient comes to an internist? One cannot be excused in this day for sizing up a patient as did the old physician and saying that he was neurotic, and, that, therefore there was nothing else the matter with him. A large number of patients who have something else the matter with them are surely neurotic too. We are all neurotic to some degree. The people who are totally phlegmatic do not amount to anything. We must be technicians, competent technicians, or else we are not competent to give an opinion about a patient. In addition, we must be clinicians and try to see through our patients. We do not need to psychoanalyze every patient.

Among the dogs we used to have at the laboratory was a group from which we tried to get gastric juice. The man who attended to the dogs, was fond of them, but sometimes he got drunk. The next morning he would be irritable with the dogs and they would slink off into a corner, and we would not be able to secure a drop of gastric juice. Usually he would come in and pat the dog on the head and say, "Hello, old fellow. How are you feeling this morning?" The dog would wag his tail and we would secure a large amount of gastric juice.

Dr. Burrill B. Crohn: One sees so much of the progress of internal medicine, of the study of organic disease such as gastric ulcer and diseases of the gallbladder and surgical conditions of the abdomen that it is a pleasure to hear of the progress and new points of view on psychogenic disorders of the alimentary tract. If one were to take the German point of view as the last word on the subject, one would find Boas of Berlin still speaking of the subject of gastric neurosis from the standpoint of monosymptomatic and polysymptomatic classification. Boas could see psychic disorders and neurogenic disorders as being represented and classified only according to symptoms. Rumination was a disease, anorexia nervosa and hysterical vomitings were entities. He could see motor, secretory or sensory disturbances as types of gastric neuroses and classify them as diseases. Fortunately, that older classification has been replaced by the point of view that all these diseases are of psychoneurotic origin. That point of view is the second move or second advance in the line of thought and was definitely emphasized at the conference at Washington last spring when this subject was discussed. At that conference one received the impression that all such diseases are purely of psychogenic origin or emotional origin. The neurogenic factor was completely missed.

The third step is represented tonight in a brave attempt to enter a new field and to define such diseases as being, at least to a certain extent, of neurogenic origin.

I say this not in the way of criticism. One would gain that impression from listening to the papers this evening. The neurogenic element has been eminently stressed, and the attempt has been made to explain disorders of neurotic origin, or many of the psychoneurotic symptoms, by definite changes in neurons and sympathetic plexuses or association neuron tracts in the abdomen or in the segmental areas or the spinal cord,

This is uncertain ground. In looking over literature one will find that on the basis of isolated or comparatively few examinations, many diseases have been attributed to changes in the plexuses, changes in the sympathetic fibers, or degeneration processes in the vagus fibers. For instance, cardiospasm, Hirschsprung's

disease and similar conditions have been attributed to degeneration of vagus neuron fibers. One finds such startling observations in the literature as regards cardiospasm, pylorospasm, and even gastric ulcer. Every review of the literature on gastric ulcer includes some remark attributing it to a degeneration of vagus fibers.

It would strike me as much more logical to attribute many of the conditions discussed to definite functional changes rather than organic ones. The work of Peterson and Müller will point out the fact that tremendous functional changes can take place from small stimuli. The injection intradermally of insulin may cause insulin shock with the congestion of the internal viscera, a marked fall of blood pressure, leukopenia and many other clinical symptoms. Such changes are functional. Many symptoms of disturbances of the autonomic nervous system are better explained on functional changes than on such an uncertain ground as toxic degeneration of nerve fibers.

You will notice how the clinicians who have entered the discussion have turned of their own accord and rather spontaneously to the clinical side and have stressed the psychic element; the papers, on the other hand, stressed the purely neurogenic element. The clinicians, to my mind, have a definite advantage in the discussion. For every possible demonstration in the literature of a definite structural change in spinal sarcoglia or nerves, there are multiple psychoneurotic elements to explain the same case.

MacLester's article stated that perhaps from 23 to 30 per cent of the patients who came to his office for examination were purely psychic or should have been approached from a psychic angle. I think his percentage is too small. Probably the percentage of neurotic patients that come to the office is much nearer to 60 or 70 per cent.

As an example of the psychic control over body function I will add one illustration, a well controlled experiment. This is the case of a woman suffering from asthma who was observed in the wards of Mt. Sinai Hospital. A control fractional curve appeared normal. This woman became much annoyed the next morning by what she considered some mistake in her treatment. A fractional test meal was ordered and taken under conditions of nervous strain. She showed marked hypersecretion and hyperacidity. Incidentally, at the same time there was a recurrence of all the asthmatic symptoms which on the previous day had been in abeyance. This again shows the definite effect of the control of the mind over the functions.

In writing a chapter recently in my book, Dr. Kardiner, who was associated with me, suggested that I omit the entire paragraphs I had written on the treatment of the neuroses and that I merely sum up the entire subject with the one sentence, "The treatment of all psychoneurotic disorders is suggestive therapy or psychoanalysis." He objected to my prescription of black medicine and pink pills saying that all such things were piffle and nonsense and that the only treatment of such disorders was suggestion by the physician to the patient. Such a theoretical position would be praiseworthy, provided all the patients to be treated had sufficient intelligence to receive suggestive therapy. Most of them have not.

Unfortunately, suggestive therapy will carry only with the more intelligent patients. In the group of ordinary intelligence one must insist on using concrete means as a method of suggestion, and such means may without loss of dignity be in the form of black medicine, pills, electric massage or hydrotherapy.

Dr. Foster Kennedy: The word "neurosis" has been used as if it were a kind of ultimate condition. Dr. Bastedo has said in quoting MacLester's paper that a large percentage of symptoms referred to the stomach were neurotic. Does that explain anything? Is a neurotic person struggling with an idea at variance with his powers of adaptation, or is a neurotic a person "inferiorly" endowed in his neurons? Is he not neurotic to the gastro-enterologic physician? Do neuroses not all come from an unstable condition of the nervous system? He can be helped, no doubt, psychically by aiding him to adapt himself to his environment. Because after all, a person with an inferior nervous system adapts himself poorly. He can be aided to adapt himself by psychic means — by suggestion, by analysis, by exhorta-

tion and by example. But fundamentally he is below par, and his symptoms come out of the same stuff and of the same web and woof as the symptoms which brand and identify him as an hysterical or neurotic person.

Among patients with chronic epidemic encephalitis there are enormous changes in automatic control — in temperature regulation, respiratory rate, intake and output of fluid, sleep mechanism — and the patients give the most extraordinary histories which sound like those of neurotic persons, of being well every other day and ill every other day. Undoubtedly they are not neurotic in the sense of this word which attributes their condition to an idea from without. They are suffering from inflammation of the hypothalamus. They are suffering from a disorder of the autonomic nervous system which interferes with their vegetative control. These same people have changed personalities. Their ability to adapt themselves to emotional situations is changed. They are no longer confident in themselves. They are shy. They avoid meetings, if they are well enough to go through such gestures. They procrastinate, they may be excited or they may be exceedingly depressed and slowed up. The whole gamut of the manifestations of the so-called functional neurosis is produced there by an organic nervous condition as gross as a fractured femur.

So it is rather unwise to use the word neurosis, or even, I think, psychogenic, as synonymous with "nothing particular," synonymous with "nothing wrong," synonymous with "a disordered condition" or synonymous with "a complex."

One wonders often if some of the essential cases of high blood pressure are not due to a pouring down of impulses, of the nature of released impulses from the basal ganglia, to the blood vessels, keeping them in a state of abnormal contraction.

The last speaker said that some of the neuroses should be treated by suggestion therapy, and he distinguished between pink pills and suggestion therapy. Pink pills are the handiest method of suggestion and the form of suggestion that the patient is prepared to receive. The pill is a vehicle for an idea rather than a vehicle for a drug. A great deal of other therapy is also purely suggestive and is only a vehicle for an idea.

None of the speakers who spoke of functional changes in the heart referred to intoxications. In France, I was struck with the fact that the men with "D.A.H.," disordered action of the heart, were emotional, nervous, highly strung, and wanted, as all of us did, to get home. But I do not believe that we paid anything like enough attention to the fact that most of the patients smoked forty cigarets a day and were allowed to continue to do so all the time they were under care for disordered action of the heart. And I wonder how many of the extrasystoles and disordered rhythms in people of middle life are due to chronic nicotine poisoning? It is nonsense to say that every man's reaction to nicotine is the same. People ask "May I smoke?" The physician usually allows the patient to smoke as much as he does himself. If he does not smoke at all he does not want the patient to smoke. That is about the level of our attitude toward tobacco. I believe firmly that a good many of the functional irregularities of the heart are due to the practice of smoking.

Dr. Walter Timme: I think that it is advisable when writing down one's diagnosis — if one ever does that — to put opposite "neurogenic" or "psychogenic" an asterisk with a footnote stating that this means "to be further investigated." The term neurogenic is never final nor is psychogenic ever final. To illustrate, if one takes certain spastic conditions in the body, relating, let us say, to the head (no neurotic headaches have been present tonight), one may have what is called a neurogenic headache; or if relating to the chest, one may have neurogenic asthmatic attacks; yet both come under the category of spasm. The sense of suffocation, the sense of pressure in the chest, the feeling of spasm of the stomach or the condition of spasm of the pylorus or spasm of the colon, and even spasm of the mind, are entities which have been dubbed neurogenic.

That one term "spasm" will answer for a great many of the symptoms called psychogenic or neurogenic which have been advanced this evening — even to the

extent of the dermatoses and angioneurotic edema, acroparesthesia, acrocyanosis. In the last few years this term spasm has received an impetus in the way of elucidation that is remarkable. The observation of Collip on the disturbances or on the effect rather of the parathyroid gland in its relation to calcium and muscle spasm are as important, if not more so, than those relating to Banting's discovery of insulin. It is found that a deficient calcium content of the blood produces a lowering of the threshold at the synapse, not only of the neuromuscular junctions but in the synaptic junction between the various ganglionic fibers. Slight stimuli, wherever they may be from, produce enormous effects, markedly more than they should physiologically. The patient is affected by a deficient calcium content in the blood to the point of an appreciation and apperception of his own physiologic functions, which normally one never has, and which creates in him fear and distress and, a neurosis, or for want of a better term an instability.

With that one determination of deficiency in one chemical element there are slain a few dozen monsters that heretofore have been dubbed and termed neurogenic or psychogenic when they are neither. They are produced by deficient calcium utilization. I believe that with progress one will find more and more that some simple element, a drop of iodine, a grain or a tenth of a grain of some other metal or element or substance will change the entire category of disease classifications and make much clearer that which is now being made more and more complex by terminology.

From the number of statements that have been made this evening regarding the effect of the vegetative nervous system, for instance, on the vital functions, it is interesting to see just exactly what a deficiency of the vegetative nervous system really connotes. That has been done. I saw recently a cat in which both gangliated cords, with the three cervical ganglia on both sides, were removed in toto and pasted on a piece of cardboard; the other exhibit alongside the cardboard was the cat, alive and doing well; it had lived for a year or more and looked like any other normal cat. There was some change in her psyche which the physiologist did not recognize. In spite of the absence of all so-called controlling factors, controlling her vital functions, there she was, vital. Probably the explanation of that is that the vegetative nervous system so-called, is simply one of the multiplicity of margins of safety that are naturally placed on all our activities for the prolongation and survival of life. On the other hand, it may connote simply that the inherent special plexuses, such as those of Meissner and Auerbach in the gastrointestinal tract, perform the actual function, and the larger vegetative system acts only in a few to control their periodicity.

Something has been said about the effect of a vagus neuritis on the stomach and intestinal functions. Also a statement was made that it has never been shown that disturbance of the vagus produced a rapidity of the heart's action. Some time ago, I did some experiments on animals in both of these fields, and in the course of the work the entire vagus was laid bare in the thorax. Surprising as it may seem, there was practically no separation of the right from the left vagus. A plexus is produced by both vagi and surrounds the entire or anterior portion of the esophageal wall whence various filaments at various levels leave the plexus. The left cannot be differentiated from the right vagus. If one pinched with forceps any one of the branches above their distribution to the cardium one caused an increasingly rapidly beating heart. If instead of applying forceps for a moment one ligated the vagus just before it descended through the diaphragm into the abdomen, the ligature being sufficient merely to produce a neuritis without causing absolute cessation of stimulus, one got peculiar results in the abdomen: there was an increase of tissue; the increase was actually to be counted in the increase in the number of peptic glands in the stomach while the size of the intestine was enormously increased. The functions of digestion and peristalsis were slowed down, but evidence of pain was not present.

The point I particularly wanted to make was that while one speaks of a neurogenic and psychogenic factor in symptomatic disturbances, one must always make that statement with the knowledge that it is not ultimate, but that underlying it is something much simpler — not more complex — simpler, if one could only find it.

Book Reviews

Questions Physiologiques d'Actualité. By Léon Binet. Price, 18 francs. Pp. 226. Paris: Masson & Cie, 1927.

In compact, simple and lucid form, Binet here presents a digest of a series of physiologic conferences, conducted under the auspices of the Faculty of Medicine at Paris in 1925 and 1926. The volume is comprised of twenty-four chapters, covering, of necessity, a rather wide range of topics, but including a number of sections definitely neuropsychiatric in their implications. These, to be specific, are the chapters dealing with the tuber cinereum, cortical ablation, circulation of the brain, sleep, the effects of tobacco and the nature and significance of the oculocardiac and so-termed solar reflexes.

In main, the discussions, while thoroughly sound and contemporary, deal with matters already having place in common knowledge, and, as such, hardly warrant detailed consideration. In this connection, however, it may prove of some interest briefly to indicate certain of the more outstanding issues and emphases. Thus, in the section treating of the tuber cinereum, particular attention is accorded its relation to the metabolism of water (Camus, Roussy), protein (Camus, Gournay), carbohydrates (Camus, Gournay, LeGrand), and fat (Camus, Roussy), with mention likewise of its apparent regulatory influence on sex function. Of no little interest in the chapter on cortical ablation is the observation, when areas subjacent to the pallium were left untouched, of retention of "psychic" gastric secretion, sex sense, and capacity for appropriate emotional response (Rothman, Zeliony). With respect to circulation of the brain, comment is made of the vasodilating effect of intellectual activity (Gley), with variable types of reaction following emotional excitation (Binet). Ligation of the vertebral and carotid arteries, although occasionally resulting in paretic and ataxic sequelae, is, in the majority of cases, succeeded by no notable untoward effect (Wertheimer and Duvillier), explainable seemingly on the basis of collateral circulation supplied by the intercostal and anterior spinal arteries. When cerebral anemia is induced by the injection of lycopodium suspension, however, a speedy and severe loss of tissue excitability is observed (Wertheimer and Duvillier). Relative to the use of tobacco and nicotine, particular mention should be made of work indicating that these agents are productive of cerebral congestion (Wertheimer), cellular pathologic changes, essentially chromatolysis and vacuolization (Guillain and Gy), and impairment of memory (Mathieu and Merklen). Regarding the conference on sleep, it is of interest that, for the most part, the medulla would appear least inhibited, with most depression found in the cortex and cord function (Rojansky, Tuttle). The question is also raised of the possible existence of a "waking center" (Lhermitte), as opposed to a specific sleep center per se, conceivably situated in the ventral portion of the third ventricle and affected by various stimuli — voluntary impulses, internal secretions, fatigue products and so-called autogenic hypnotic substances.

While nothing of especial importance is brought out as regards the oculocardiac reflex, the section on the "solar" reflex (Claude, Thomas) merits at least passing comment. This reflex is measured by the effect of pressure applied to the celiac plexus on arterial tension, as portrayed by manometric oscillation. When the oculocardiac reflex is negative or inverse, the "solar" response shows striking diminution of manometric fluctuation, whereas when the oculocardiac response is positive, the manometer record, as a result of epigastric pressure, either is free from essential oscillation change or is characterized by some degree of increase. These "solar" effects, it is thought, are dependent in cases marked by lessened oscillation on vasodilation affecting the abdominal field, and in instances in which the response is reversed, on vasoconstrictive tendency. From the data presented, the conclusion is finally reached that the "solar" reflex may be taken

as a reliable index of thoracolumbar sympathetic tone or excitability, in contrast to the oculocardiac reaction which is assumed to represent a similar sign for the vagus system.

Brain and Mind, or the Nervous System of Man. By R. J. A. Berry, M.D., F.R.C.S., F.R.S. Price, $8. Pp. 586. New York: The Macmillan Company, 1928.

The fundamental idea back of this book is to show that what is called the mind is the result of the activity of the nervous system. In the present day of psychologists and near psychologists as well as psychoanalysts, and the ever increasing number of books on psychologic subjects written obviously for the purpose of selling, it is high time to look at the fundamentals of psychology or behavior. It is a curious thing that whenever the "mind" is concerned many writers assume that the brain has nothing whatever to do with it. This book, therefore, coming as it does from a man qualified to write on this subject, is greeted by the reviewer with a sense of relief, for it goes back to first principles and in a book of almost 600 pages, 446 are devoted to the anatomy and physiology of the nervous system. This part is well done, and the reader will be able to obtain from it an adequate idea of the anatomy and function of these structures.

The second part deals with what the author calls the nervous system in health and disease. The importance of the nervous system is again emphasized in the caption "no neurone no mind." He has little time for psychologists without a neurologic background and even less for psychoanalysts. In discussing the latter topic the following statement is of interest, "that, whilst the calls of sex are undoubtedly a driving neurological force, there is no physical foundation for most of the puerile indecencies of certain Continental schools. That control over sexual thoughts and reactions depends on the state of development of the inhibiting supragranular layer of the cortex, and that, where this is deficient, as in many aments, it is more than likely that therapeutic treatment by suggestion or psychoanalysis will be productive of more harm than good, because, by directing the patient's attention to the condition, it may actually stimulate, rather than inhibit, the secondary causes of desire. If the cortical controlling cells are not there, no human agency can put them there."

He calls attention to the function of myelinization and the importance of myelinization to mentality, and states that persons in whom this process ceases earlier in life as a consequence attain a lessened degree of intellectuality, and on the average have heads of smaller size. To him, emotions are the result of incoming enteroceptive, proprioceptive and exteroceptive impulses transmitted to the cerebral cortex and dispersed through the innumerable granular and other inter-uncial neurons of the cranial associated areas.

He then discusses the various types of amentias, this term being used more by British than by American authors. He makes the significant statement that were a systematic microscopic examination made of the cortical cells of all patients who have died after having suffered from many of the neuroses and the so-called psychoneuroses, it is probable that amentia would be found to be the common underlying physical factor; and that the underlying basis in neurasthenia is an imperfectly conducting and improperly functioning brain, the result of the lack of vitality of the cortical neurons. It is obvious from all this that the neuroses have a definite organic basis.

Not the least interesting part of the book is when the author describes his method for the diagnosis of amentias and gives his experiences in the primary amentias. Lastly there are illustrative cases. Altogether it is a refreshing and stimulating book which departs from the usual claptrap manner which psychologists employ and gives a fundamentally sound basis for clinical symptoms.

The Kuhlman-Binet Tests for Children of Preschool Age. Florence L. Goodenough. Price, $2. Pp. 146. Minneapolis: University of Minnesota Press, 1928.

Although the Binet test has proved its reliability as an instrument to measure the intellectual capacity of children of school age, psychometric tests for children

of preschool age, particularly the Kuhlman modification of the Binet, have not been standardized on large enough numbers of such children to give them the same degree of reliability. Furthermore, the Binet test gives a fairly constant result when applied several times to the same child over a period of several years, but when preschool children have been retested by the Kuhlman modification, a wide variation has been found in the results. This may be due to defects in the test itself, or to an actual variation in the rate of mental growth in the preschool period.

The author has applied the Kuhlman modification of the Binet test to the largest group of children of preschool age yet tested. In all, 495 children selected so as really to be a representative specimen of the population of Minneapolis were examined, and 300 of these — 100 at 2, 3 and 4 years of age, respectively — were reexamined after a period varying from four to seven weeks. Her results indicate that the law of negative acceleration in growth holds true for mental development in the preschool period, although it proceeds more rapidly then than during later years. There were some wide variations in the results of retesting, but these can be explained on defects in the tests used. In giving the tests, the effect of physical health and emotional attitude on the results was taken into consideration, and the methods used to overcome the latter difficuly are discussed fully. There is a full discussion of the reliability of each test and its suitability for the age group in which it was placed.

The material collected leads to a number of interesting conclusions. Even at 2 years of age, the intelligence quotient of children from the professional classes is higher than that of children from the laboring classes. The former also gain more rapidly than the latter, who either show no gain or actually lose. The intelligence quotient of children who have been attending nursery school and so have been subjected to intellectual stimulation does not increase more rapidly than that of children selected carefully to resemble the former group who have never attended nursery school.

The book is a valuable contribution to the subject of psychometric testing of the preschool child.

Epilepsy. Comparative Pathogenesis, Symptoms, Treatment. By L. J. J. Muskens, M.D. Foreword by Sir Charles S. Sherrington. Price, $8. Pp. 442. New York: William Wood & Company, 1928.

It is rare for a neurologist to maintain a special interest in a particular disease or entity, for the nature of the subject is such that if one is practicing neurology, one's interests must necessarily be large. On the other hand, if it is possible to direct one's scientific interest and research in one special field, such an excellent book as this by Muskens will come from the pens of neurologists. That this is desirable there is no question.

For fifteen years the author has been working and writing on epilepsy from both the experimental and the clinical standpoints, and he has produced a book which is certainly the best exposition of epilepsy today; it not only bears the summation of a life time of investigation on the clinical phases of epilepsy but also gives an interesting summary from the standpoint of research. That neurologists are still far from having any real knowledge of the causation and mechanism of epilepsy is evidenced by the results obtained in the recent meeting on epilepsy held before the Association for Research in Nervous and Mental Disease. However this may be, it is obvious that any research will bear fruit if it is carefully done.

The outstanding feature of Muskens' work and the thing which impresses itself on reading this excellent book is the fact that epilepsy really should be studied before the first fit appears and that a great deal can be done in the management and treatment of epilepsy if one studies carefully the history of the onset and the early manifestations. The management of epilepsy also is not an easy matter and the author emphasizes the carefulness with which every little detail should be

gone into if one expects good results. Too little attention has been paid to the preconvulsive stage in epilepsy. Such articles, for example, as are now appearing in the current numbers of the ARCHIVES by Patrick and Levy on the preconvulsive manifestations emphasize the importance of such studies.

The investigative end is the result of many years of work carefully done and checked up with the results of other authors.

Altogether it is an excellent work. Only a hint is given in this review of its value. Every neurologist should read it, for he will surely profit by it.

PRAKTISCHE DIFFERENTIALDIAGNOSTIK FÜR ÄRZTE UND STUDIERENDE. Volume II. Neurology. By PROF. DR. WALTER RINDFLEISCH and DR. WALDEMAR UNGER. Published under the direction of Prof. Dr. Georg Honigmann-Giessen. Paper, price, 18 RM.; cloth, price, 20 RM. Pp. 291. Dresden and Leipzig: Theodor Steinkopff, 1928.

Under the heading of Practical Differential Diagnosis for Physicians and Students there is appearing now a series of seven volumes. The general editor of the series is Prof. Dr. Georg Honigmann-Giessen. The first volume on internal medicine has already appeared. The second volume on neurology, which is here reviewed, is under the editorship of Prof. Dr. Walter Rindfleisch and Dr. Waldemar Unger. Number three is to be on psychiatry, and the other volumes on surgical and other topics.

The neurologic volume, of about 290 pages, has two general divisions: (1) on the organic nervous diseases, and (2) on the psychoneuroses and functional disturbances. The first part is written by Rindfleisch and the second by Unger. Obviously, in 153 pages it would be impossible to cover all of organic neurology, but enough is given so that a student would gain some idea of the subject talked about. For example, tabes has six pages, brain tumors six pages and so on. The illustrations are not adequate, and there are not enough of them.

NOUVEAU TRAITÉ DE MÉDECINE. XVIII. PATHOLOGIE DU SYSTÈME NERVEUX. By DR. G. H. ROGER, M.D.; DR. F. WIDAL, M.D., and DR. P. J. TEISSIER, M.D. Price, 85 francs. Pp. 802. Paris: Masson & Cie., 1927.

Two previous volumes of this series have already been reviewed. The present volume, No. 18, covers a diverse field. Practically all of the articles are by French authors with the exception of a few such as that on vertigo which is written by the Swedish neurologists Karl Petrén and Sven Ingvar.

The first of the general headings which comprise this volume consists of Symptomatology of the General Nervous System, under which are discussed coma, apoplexy, headaches, vertigo and sleep disturbances. As only ninety pages are devoted to this part, the discussion is necessarily sketchy. The second division, comprising eighty-seven pages, deals with psychiatry. The third division is on language disturbances, and here there is an excellent discussion on aphasia by Charles Foix and a smaller chapter on dysphasias and dystonia by Henri Meige. The next few divisions treat allied topics, such as motility, tonicity, electrical reactions and disturbance of reflexes. Then there is an excellent chapter on sensory disturbances by Madame Dejerine and E. Gauckler. This is followed by chapters on the eye, the ear and the spinal fluid.

This volume compares favorably with the previous ones and like them represents the modern French point of view.

A TEXT BOOK OF PSYCHIATRY FOR STUDENTS AND PRACTITIONERS. By D. K. HENDERSON, and R. D. GILLESPIE. Pp. 508. New York: Oxford University Press, 1927.

A successful textbook on any subject is a rare achievement. This is particularly true of books on psychiatry. Henderson and Gillespie's work therefore is outstanding in the fact that it belongs to this class. The aim of the book is to present psychiatry from the biologic point of view of Adolf Meyer. This biologic

hypothesis regards mental illness as the accumulative result of unhealthy reactions of the individual mind to its environment and seeks to trace in a given case all the factors that go to the production of these reactions. The book begins with a historical review of the care and treatment of mental disease and is followed by an interesting chapter on classifications, in which there is a resumé of most of the classifications in use at the present time. One is inclined to agree with the authors who state that no attempt at psychiatric classification is entirely satisfactory and that the important thing is not to sort the patients but the facts. After discussing various classifications they recommend the scheme followed by Meyer.

The next chapter, on etiology, is equally interesting, as is the rest of the book. Clinical histories of patients are used throughout so as to give the reader an idea of types of cases. All through the book the American literature is constantly quoted as is to be expected of the authors who have had some of their training in this country. The book is to be recommended as a sane, informative and creditable discussion of the modern trend of psychiatry.

Syphilis. A Treatise on Etiology, Pathology, Symptomatology, Diagnosis, Prognosis, Prophylaxis and Treatment. By Henry H. Hazen, A.M. M.D. Second edition. Cloth. Price, $10. Pp. 631. St. Louis: C. V. Mosby Company, 1928.

In the present state of medical knowledge it is impossible for any author to write a textbook even on a single topic. This is well illustrated in the second edition of Hazen's work on syphilis, in which many of the chapters have been written by others. The first edition appeared about ten years ago. There have been many advances in the knowledge of this disease since that time, and this book gives an excellent summary of present knowledge. To neurologists the chief interest is the chapter which deals with involvement of the nervous system. This is obviously written for the dermatologist and not for the neurologist. The chapter dealing with the incidence of syphilis is interesting. It would seem from this that among the hospitalized class of negroes syphilis is about one and a half times as frequent as among the whites. The author makes the statement that there are about eight million syphilitic persons in this country, and he quotes Leredde who states that syphilis annually causes 25,000 deaths in France. Altogether this is a good general book on the subject.

Mental Disorders. A Handbook for Students and Practitioners. By Hubert J. Norman, M.B., Ch.B., D.P.H. Price, $5. Pp. 443. New York: William Wood & Company, 1928.

There have been perhaps more textbooks on psychiatry in the last year or two than for many years, and it is interesting that many of them have come from the hands of British authors. Most of them have been a credit to British psychiatry, and it is an indication of the live interest that psychiatry is undergoing. The present book is for the student and practitioner and is a handbook. The subject matter is well presented although necessarily brief. For the purpose it is adequate.

Morton Prince and Abnormal Psychology. By. W. S. Taylor. Price, $1.75. Pp. 137. New York: D. Appleton & Company, 1928.

It is rarely that a medical contemporary writer has the compliment paid him of having his work discussed in a single volume. That Dr. Morton Prince deserves this there is no question, for he has been one of the outstanding contributors and leaders in the field of abnormal psychology, especially in this country. Professor W. S. Taylor, who presents this volume, summarizes Dr. Prince's point of view, which to most neurologists is well known.

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CONTENTS